

Data Privacy Management (DPM) - A Private Household Smart Metering Use Case

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ABSTRACT

The automated collection of real life data in private households places special requirements on a *Data Privacy Management (DPM)* concept. The development and implementation of a *DPM* concept for use in a scientific environment is demonstrated according to a successful use case – the project *BLADL*.

The intention of this paper is to provide a guideline for ethical and privacy-preserving data collection and management in research projects in the EU.

CCS CONCEPTS

• **Security and privacy** → **Privacy protections**; *Social aspects of security and privacy*; • **Information systems** → **Process control systems**.

KEYWORDS

Data Privacy Management, Privacy, GDPR, Ethics, Data Collection, Dataset, Scientific Data, Process Management, Smart Metering, Elderly

1 INTRODUCTION

Data is key. Not only for research, but also industry and society, it is essential to collect, manage (refine, annotate, etc.), and publish in a sustainable way [5, 22]. Data enables researchers around the globe to conduct their studies, verify and substantiate their hypotheses and innovates. With the afreshed rise of artificial intelligence (Machine Learning [2], Deep Learning [13], etc.) data is the key driver for innovative research and applications across most domains, e.g., medicine, robotics, automotive, financial sector, industry or aerospace [3, 6, 11]. Thus, added value is generated for many stakeholders. To enable and reinforce these advances, it is, and always will be, necessary to use real data, which can be personal and sensitive. To protect this personal data, it is required to follow appropriate data protection law, i.e., the *General Data Protection Regulation (GDPR)* [9] in the EU.

Therefore, the challenge is to collect, manage and provide real data (qualitative and quantitative) while privacy concerns are covered.

To address this challenge *Data Privacy Management (DPM)* is conducted, which is exemplified according to a use case in which smart metering data is collected from private households of elderly people.

The main contribution of this paper is to outline the use of the *DPM* process in an context, in which consent from elderly people is required to give a guideline for other research projects.

The remaining of the paper is structured as follows: The goals, background and challenges of the use case – the project *BLADL* – are detailed in section 2. In section 3, the legal basis and requirements for the data collection and management process are detailed, whereas their implementation as a *DPM* process is demonstrated in section 4 and section 5. Overarching ethical concerns are covered in section 6. The practical experiences with the *DPM* process are reflected and discussed in section 7, before the paper is concluded in section 8.

2 SMART METERING USE CASE – BLADL

The goal of the project *BLADL* (*Better life in old age through digital solutions*) is to support elderly in their daily living by using digital technologies. For this purpose, both active (e.g., voice user interfaces) and passive (e.g., sensors, smart meter) technical solutions will be installed in test households. These are intended to support the residents in their everyday life on the one hand and to identify potential emergencies on the other.

As a passive solution in *BLADL* an approach is investigated to detect deviations in everyday life by using power consumption data – collected by smart meters¹. Therefore, we first disaggregate the power consumption data to acquire information of the electrical devices used from the resident. Based on the usage of electrical devices, the residents activity is derived [21], e.g., when switching on a hotplate it can be inferred, that the resident is currently performing the activity ‘cooking’. The information of the current user activities allows the creation of individual activity profiles, which in turn can indicate possible emergency situations due to the detection of anomalies.

To perform the disaggregation of the power consumption data – which is commonly known as Non-Intrusive Load Monitoring (NILM) – it is first required to develop intelligent algorithms, which are trained by a labeled data set [23]. In the project scope of *BLADL*, a labeled data-set is collected from 20 private households of mostly elderly people. Therefore, on the one hand, a smart meter was used to collect the total power consumption and on the other hand single power measure tools on 10 selected devices in each household were installed.

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¹As smart meters, the commercially available Q3M devices from EasyMeter GmbH, Bielefeld were used with the smart meter gateway *Discovergy Meteorit 2.0* from Discovergy GmbH, Heidelberg

Due to the fact that data collection is performed in the private domain of the residents, a particular attention must be paid to privacy regulations and ethical issues, next to technical aspects. The challenge is to obtain qualitative and quantitative real-data for the development of appropriate intelligent algorithms. In *BLADL* Motif Clustering [15] was used to extract common consumption patterns – called *motifs* – from the label data recordings of the individual devices. In a second step the previous extracted motifs were identified in the total power consumption of a household using the MASS - Motif Search [16] algorithm. This enables determining the activity state of individual devices in the case of matching motifs.

To conduct empirical research, it is furthermore necessary to collect additional label data to the raw data in order to be able to carry out well-founded evaluations. A critical point is the availability of labelled data, as *Cardinaux et al.* [7] has already noted in his work. They proposed a model for identifying potential emergency situations in private households. Although they were able to detect anomalies in the daily behavior, they could not validate whether the situation was an actual emergency situation.

Therefore, in *BLADL* a labeled data set was collected allowing the extension and validation of this algorithms. Furthermore, this data set enables developing new approaches for NILM or emergency detection.

Parra et al. [17] noted that elderly people usually have several health afflictions. It is important to know that most of elderly people (61% of men and 75% of women) live alone or with his/her old partner. The ones who live alone generally have more accidents. In fact, 30% of them have one fall per year and the 50% of them even suffer more than one fall. [17]. Hence, we collected the data mainly in the residences of elderly peoples, which represent the main target group for emergency systems.

Due to the necessary of constant monitoring of the residential environment, privacy and data security requirements (i.e., BayDSG[12] for *BLADL*; more general GDPR[9] for Europe) are of particular importance.

3 LEGAL BACKGROUND

The *General Data Protection Regulation (GDPR)* has been enforced in Europe since May 25th 2018 constituting the principles *Privacy by Design*, privacy requirements have to be considered during the design and planning, and *Privacy by Default*, the default settings and processes must guarantee the privacy of individual for all technical systems [9, Art. 25]. This naturally also encompasses storage of personal data in databases and data-warehouses. The processing of personal data is in general prohibited and requires, simply stated, a valid lawful reason [9, Art. 6]. In fact, various requirements are imposed on the processing of personal data, e.g., the processing must be lawful, fair, and transparent for a specific purpose (and limited only to the purpose) and the data has to be protected [8]. The valid reason can hereby a given legal basis, e.g., requirement for data collection by law or for a public interest. Another valid reason to process personal data is the explicit consent of the subject, which has to be given informed and freely [9, Art. 7]. Although it may be argued, that the collection of data for scientific reason may be for a public interest, thus fulfilling the conditions for a legal

basis. Personal data processed for scientific research purposes is also covered by the *GDPR* and can be interpreted in a broad manner. This includes studies conducted in the area of health for public interest. Because for the purpose of research, data may be published measures have to be put into place to protect the individuals, especially if health data is processed [9, Recital 159]. Although, *GDPR* enables the processing of personal data for scientific research, the explicit consent of the participants has been obtained to make the process as transparent as possible for the subjects.

The consent has been obtained in a written form, whereas the details of the processing of the personal data is layed out to the participants in a privacy policy [9, Art. 13]. Hereby it is stated, among other essential information, that the purpose for the processing of the data in *BLADL* is 'research', which of course is elaborated in detail in practice (see section 5 and section 7).

It has to be considered that it is a challenge to actually inform the users, i.e., elderly people, about the processing of their personal data. This has been already addressed in the literature by various authors by either criticizing the readability [14], or proposing methods to improve the readability of privacy policies in general [18] or for a specific target audience [1].

Other concerns that have to be taken into account is the type of the processed personal data and the methods applied on them, especially profiling or automated decision-making [9, Art. 22].

For the given use case, the collected data are used for disaggregating and inferring to the wellbeing of the elderly, therefore the collected data falls under the special category of personal data, i.e., health related data, which is in general prohibited to be processed [9, Art. 9]. But, for the purpose of research an exemption is made, which enables researchers the processing of such data categories [9, Art. 9(2)(j)], but only if stronger measures to protect sensitive data appropriately are established [9, recital 53].

In *BLADL* based upon the collected data, intelligent algorithms are developed to detect anomalies in the behavior of the participants to detect potential emergency situations. This may fall under the terminology of profiling or automated decision-making and is therefore in general not allowed [9, Art. 22]. Such processing is only allowed, because consent is given by the participants [9, Art. 22(2)(c)]. Thus, the consent of the participants is essential to enable the collection of data and their processing for research.

Additional aspects of the *GDPR* are considered for the *Data Privacy Management (DPM)* in the following including *Data Retention* and *Data Subject Rights*.

4 DPM IMPLEMENTATION CONCEPT

The *GDPR* [9] contains legal requirements which must be complied with when collecting personal data. It is therefore not relevant, whether the data are collected directly (e.g., requesting account information) or indirectly (through reusing existing data which are not originally collected for the specified purpose, e.g., activity detection through smart meter measurements) from the data subject. First it is required to define:

- the purpose and legal basis of data collection and processing [9, Art. 13(1)(c), Art. 14(1)(c)]
- all data values which are collected and assigned direct or indirect to a specific person [9, Art. 14(1)(d)]

- the categories of recipients to whom the personal data will be disclosed have to be identified. This can be internal or external parties, whereby the external parties must be listed individually [9, Art. 13(1)(e), Art. 14(1)(e)]
- for each of the identified data object deadlines for deletion [9, Art. 13(2)(a), Art. 14(2)(a)]

In order to determine further necessary organizational and technical requirements, a general privacy impact assessment has to be considered, where on the one hand, the gravity of the potential loss and, on the other, the probability that the event and the consequential losses will occur are assessed. If the data are categorized as 'high' risk, a detailed impact assessment must be created [9, Art. 35].

As a next step, the data subjects have to be informed in an appropriate way about the data processing. Based on the kind of data collection, the data subjects must be informed about the process and purpose of collection, the recipients, the retention deadlines, the forwarding of the data and their rights for disagreement. The data subjects must be informed about the process of data collection and all corresponding technical and organizational tasks. Furthermore, the persons must be informed about possible costs, time expenditure and restrictions (e.g., the single power measurement tools must not be unplugged during the test phase).

With the *GDPR* several *Data Subject Rights* [9, Art. 12 - 23] have been introduced, which enables the data subject to make various demands that have to be fulfilled. First of all, the participants have to be informed about their *Data Subject Rights* [9, Art. 13(2)(b), Art. 14(2)(c)]. The *Data Subject Rights* encompass, that the user can demand to access their personal data [9, Art. 15], correct their personal data [9, Art. 16], delete their personal data, restrict the processing of their data [9, Art. 17], object the processing of their data [9, Art. 21], and right to data portability [9, Art. 20]. To make use of these rights detailed conditions and obligations have to be followed. Therefore, it is required to be able to correlate the data and the purposes, for which the data is processed to the participants.

Further, to ensure integrity and confidentiality of the data recordings a procedure-specific IT security concept should be created. All technical and organizational measures must be taken to ensure a level of protection of personal data commensurate with the risk [9, Art. 5(1)(f)] .

5 DPM IMPLEMENTATION IN BLADL

In the following the implementation of the *DPM* within the project *BLADL* will be outlined.

The planning and validation of the *DPM* concept was carried out in cooperation with the data protection officer of *Deggendorf Institute of Technology* and the internal expert for *Applied Ethics and Sustainable Development in Health Science*.

5.1 Purpose of the data processing

The data collected in the project are used for the purpose of 'scientific research', to develop and validate algorithms.

5.2 Definition of data subjects

In the project *BLADL*, the data subject includes the residents of the households to be observed and specified contact persons.

5.3 Definition of data objects

Table 1 shows the personal data collected in the project *BLADL*.

Table 1: Data collected in the project *BLADL*

data object	purpose
Name	accounting, implementation
address	implementation
e-mail	implementation, information
birth date	statistics
sex	statistics
(mobile) phone number	implementation, information
bank account data	accounting
contact person	information
internet connection available	implementation
number of residents	statistics
number of rooms	statistics
living space	statistics
type of heating	statistics
smart meter ID	implementation
smart meter measurements	implementation, analytics
single power measurements	implementation, analytics
assignment of single power measure tools and location	implementation

5.4 Rights of data subjects

The time-frame to comply to *Data Subject Requests*, i.e., Art. 15 to 22, is one month. If possible, the request should be answered without undue delay. This time-frame can be extended by additional 2 month (up to 3 months), depending on the complexity and number of requests [9, Art. 12 (3)]. Thus a manual processing is viable, if not too many requests are made.

Due to the collection process, in which each device and household is identified, the data is assigned via such identifiers. Although data is anonymized for open access publication, a raw version of the data is archived. If a request of a participant for one of its *Data Subject Rights* is conducted, it is relatively easy to identify the related personal data and fulfill the request. It has to be noted, that up to this date no request for a *Data Subject Right* has been made. Thus, no practical experience is available on this matter besides the preparation to fulfill such requests.

5.5 Data recipients

In our project, only the project staff could be identified as internal parties, they use the personal data for scientific research.

Table 2: Data retention

data object	retention
Name	delete
address	delete
e-mail	delete
birth date	delete
sex	delete
(mobile) phone number	delete
bank account data	delete
contact person	delete
internet connection available	delete
number of residents	k-anonymize
number of rooms	k-anonymize
living space	k-anonymize
type of heating	delete
smart meter ID	delete
smart meter measurements	anonymized
single power measurements	anonymized
assignment of single power measure tools and location	anonymized

External parties includes the 'Koordinierungsstelle für Datenverarbeitung an der Hochschulverwaltung an den staatlichen Fachhochschulen in Bayern' for the purpose of transmission of personal data for internal accounting purposes. Furthermore, the data will be forwarded to the 'Staatsoberkasse Freistaat Bayern' for payment.

5.6 Data Retention

We divided up the data subjects into three categories. The first category (delete) includes the data subjects, which will be deleted until the project is finished. The second category (k-anonymize) contains data which will be k-anonymized ($k = 4$) by creating clusters (e.g., number of residents $<2, \geq 2$). The third category (anonymized) containing the measurement data which are fully anonymized by removing all identifiers and will not be deleted. The retentions are listed in Table 2.

5.7 IT-Security concept

In the project, therefore we only used the internal IT- infrastructure of the *Deggendorf Institute of Technology (DIT)*. This ensures confidentiality, integrity, availability and reliability of the storage servers. Furthermore, the procedures for periodic review, assessment and evaluation are ensured.

5.8 Information requirements

We provided all directly involved participants a written 'Declaration of consent to the collection and processing of personal data'. This consent includes the information of data objects, the purposes for data collection, data recipients, rights for disagreement and consequences of disagreement.

Information on the risks were not required due to previous risk assessment, which was considered with *Wilhelm et al.* [20].

5.9 Privacy impact assessment

We realized the privacy impact assessment based on the 'Risiko-modell für Datenschutzfolgeabschätzungen' of the *Bavarian State Office for Data Protection Supervision*[4] due to a three-step assessment (Risk: high; middle; low). In agreement with the responsible data protection officer, we categorized our project data as 'middle' risk, caused on the fact, that the data allows creating profiles of the data subjects. Through the k-anonymization ($k = 4$) the risk for third-party usage is minimized.

5.10 Process description

In the project *BLADL* we created an extended participant information folder, in which the scope of the research project, the kind of the data, the process of the experiment, the taken safety and security precautions and the contact persons from the data recipients are listed. All participants received the information folder in advance of the data collection.

To collect, process and analyze data on power consumption in private households concerned, a *data usage contract* was concluded with each of the test persons. This contract contains the following points: (1) Name, address and contact details of the contracting parties (2) Description of the subject matter of the contract (3) Information requirements (4) Purpose and legal basis for data processing and categories of recipients (5) Duration of the right for storage and processing (6) Rights for disagreement (7) De-Anonymization (8) IT-Security concept (9) Compensation of expenses (10) Pushing of the data results (for academic purposes) (11) Consequences of breach of contract (12) Notes on the procedure and implementation process (13) Regulations on contract amendments (14) Date and signature of data subjects and data recipients.

6 ETHICAL REFLECTION (OPTIONAL)

In order to comply with ethical norms and values, as well as a maximum of process transparency for the test participants, an ethical reflection on the project (especially for the data collection and further processing) can be created optional.

We created a ethical reflection based on a guideline of the *Ethics Commission DGP e.V.* [10], which was published by *Wilhelm et al.* [20]. Thereby, we analyzed and described the procedure for selecting participants, the possible risks for participants and preventive measures and how we ensured an informed consent for participating in the project.

7 PRACTICAL EXPERIENCES

Between September 2019 and April 2020, we collected the total power consumption data of 20 households in Germany using conventionally available smart meters with a resolution of about 1Hz. In addition, we measured the individual power consumption of 10 devices in each household, where the electrical load indicates direct human interaction [19].

We started in Februar 2019 searching and testing suitable technical devices, to fetch the relevant data in the households. Therefore, we realized a technical setup containing smart meter, HomePlug AV, single power measurement tools and a single-board computer. After the process of selecting suitable hardware, we tested out possibilities for sending the measurement data from the private

households to the internal server of the *DIT* in a secure way. We decided to use a VPN tunnel between the single-board computers, which collected the data of the individual measurement tools inside the households, and the storage server at the *DIT*. To prevent attacks from the local home network, we used a separate router, which sets up a dedicated and independent network. Furthermore, we blocked all LAN Ports via software blockings and using hardware port blockers. We included an integrated monitoring and automatic notification system to identify unauthorized accesses.

In the next step (Mai 2019), we set up a data privacy concept as described in section 4.

In order to comply with ethical norms and values, as well as a maximum of process transparency for the test participants, an ethical reflection on the project was created at the same time (see section 6). Starting from Juni 2019 we searched for suitable test persons. Therefore, we used mainly personal contacts from our previous research. We tried to recruit test persons in information events and single info sessions. It is notable, that only single info sessions were suitable to recruit test persons. The reason for this can be seen in the fact, that the process of data collection, and also the type of further use for the test persons is very complex and must therefore be explained individually.

After the test persons had agreed to participate in the project, we handed them a comprehensive participant information folder and discussed all process steps, again personally. Only after the participants had understood all process steps the data usage contract was presented to them for signature.

As a next step in September 2019 the actual data fetching process could be started with installing the corresponding hardware in the households. The installation of the technical components was exclusively performed from staff of the *DIT*, the test person himself did not have to actively help. When installing the hardware, we introduced the test persons in usage of the devices to intervene during hardware-failures. We ensured to be available for the test persons via telephone also outside office hours.

Even we selected the hardware carefully and tested the setup extensively in previous, during the test periods some failures occurred. The most common are listed below:

- loss of connection – single measurement tool
- failure – single measurement tool
- loss of connection – smart meter
- failure – smart meter gateway
- (permanent) internet connection failure
- unauthorized user intervention

After the test setup stayed in the households for 28 days on average, we uninstalled the setup in households completely.

Before publishing we k-anonymized ($k = 4$) the data set by removing all unique identifier and cluster all statistical information which can be used to re-identify the persons (e.g., number of residents). This aggregation allows using this data objects for statistical purposes, but cannot be used to re-identify individual persons. The personal information, which are not required any more, was deleted.

Although not scientifically measured, the study participants were overall satisfied with the handling of their data, i.e., the established

DPM process. Especially the thoughtful integration of their concerns in public meetings and having direct contact person was thanked. To this date no request for a *Data Subject Right* has been made. The project allowed interesting insights [19] and enabled interesting follow up research.

8 CONCLUSION AND FUTURE WORK

This work outlines our process for *DPM* when collecting data (in private households). The process steps were carried out in the context of a practical example from a part of the project *BLADL* (*Better life in old age through digital solutions*), and can be used as a guideline for data collection in other projects (e.g., when developing social media applications).

In addition to the legal and theoretical aspects, particular importance was attached to practical experience in the research context. In practice, the legitimacy of the processing of personal data should be carefully pondered. *GDPR* allows several reasons, under which personal data can be processed [9, Art. 6]. The use of consent, although used in our use case in combination with the scientific purpose, is often avoided in practice, because it requires the fulfillment of various conditions or properties for the consent [9, Art. 7]. Thus, proper consent management may be argued to be hard. Special attention should be taken to the type of personal data that is processed, e.g., health related data, which requires special care for the processing and protection of personal data.

The collection and sustainable management of data is essential for research, industry, and society. The handling of personal data requires even more care, which requires interdisciplinary expertise (privacy, ethics), which we intended to share with this work. To ease these processes, we see it as a necessity that competences for *DPM* are collected, structured and provided as a centralized service to researchers on a state, federal, and international level.

This does not only apply for *DPM*, but also other essential competences (e.g., Anonymization and Pseudonymization, Technology Assessment) that are required for efficient and sustainable data management and research.

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