Automated Privacy Audits to Complement the Notion of Control for Identity Management

Rafael Accorsi

Department of Telematics
Albert-Ludwigs-Universität Freiburg, Germany
accorsi@iig.uni-freiburg.de

Abstract. Identity management systems are indispensable in modern networked computing, as they equip data providers with key techniques to avoid the imminent privacy threats intrinsic to such environments. Their rationale is to convey data providers with a sense of *control* over the disclosure and usage of personal data to varying degree, so that they can take an active role in protecting their privacy. However, we purport the thesis that a holistic sense of control includes not only the *regulation* of disclosure, as identity management techniques currently do, but must equivalently comprise the *supervision* of compliance, i.e. credible evidence that data consumers behave according to the policies previously agreed upon. Despite its relevance, supervision has so far not been possible. We introduce the concept of *privacy evidence* and present the necessary technical building blocks to realise it in dynamic systems.

1 Introduction

In a technological setting where some even prophesy the death of privacy [5], the need for approaches to mediate and legislate for the collection of personal attributes and their usage is increasingly gaining in momentum and relevance. While such an investigation involves interdisciplinary efforts, we focus on the technical aspects. In this context, identity management systems (henceforth IMS) play an essential role in circumventing the privacy threats inherent to the deployment of information technology. They allow data providers to selectively disclose attributes to data consumers, possibly enabling data providers to formulate policies under which collected attributes can or cannot be employed.

The rationale of IMS is to convey a sense of control to data providers, where the "control" stands for the *regulation* of attribute disclosure. However, data providers today obtain no indication as to whether data consumers actually behave according to the policies agreed upon. Put other way, data providers are left with a number of privacy promises or expectations, but obtain no creditable evidence that their policies have been

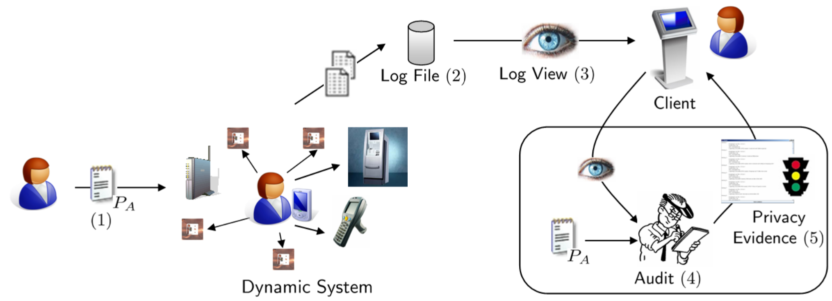


Fig. 1. The workflow for privacy evidence.

to realise the concept of privacy evidence. These building blocks are then described sequentially: in §3, we introduce a language for the expression of privacy policies; in §4, log views based on a secure logging service are presented; and in §5, we describe our approach to auditing log views based on the stated privacy policies. We discuss our work and provide perspectives for further work in §6.

2 Technical Setting and Building Blocks

The realisation of privacy evidence anticipates the steps depicted in Fig. 1. In (1), a data provider A formulates a policy P_A and communicates it to the data consumer. Since we consider dynamic systems with implicit interactions, we assume that policies are communicated before joining the system. (Implicit interactions take place without the awareness of the data provider.) When interacting with the system, a number of events are recorded as entries in log files (2). In fact, we assume that *every* event is recorded, so that log files offer a complete digital representation of the activity in a dynamic system. At some point in time the data consumer may retrieve the log view S_A containing all the log entries related to A (3). A can then visualise the collected data and start a third-party automated audit process (4) to check whether the policies P_A have been adhered to, thereby generating the corresponding privacy evidence (5).

To realise privacy evidence, the following central technical building blocks are essential: a *policy language* for the expression of privacy preferences in dynamic systems; *log views* to allow the visualisation of recording activity; a *secure logging* to ensure the authenticity of recorded data, in particular to improve the credibility of log views; and an *automated audit* process for checking the adherence to policies. In the forthcoming sections, we describe the work towards the realisation of privacy evidence.

Assumptions. In our work, we consider the following assumptions. First, *every* event happening in the system, as well as every access to collected data is recorded as an event in a log file. Second, on interacting with the system, data providers are identified while the events they are involved in are recorded. That is, the entries in the log file are always related to a data provider. Third, while the system is dynamic in that it adapts itself to the data providers' preferences, it is static regarding the data collection possibilities. Technically, this means that the ontology describing the system does not change over time and, hence, the policies of data providers do not become obsolete. Although these assumptions do not hold in general, they hold for some scenarios, as the one we consider in §6.

3 A Policy Language for Dynamic Systems

A policy language allows data providers to specify a set of rules, i.e. a policy to regulate the access to their attributes, whereas execution monitors on the data consumers' side enforce these rules and record the authorisation decisions for further inspection. However, in dynamic systems the sole expression of access rights is not enough. Policies for dynamic systems should also allow data providers to express which attributes may or may not be collected. The policy language we propose therefore builds on two notions: *access* and *collection*. In contexts where the distinction between these notions is irrelevant, we simply refer to them as an *act*.

We enrich atomic acts with conditions for *usage control*. Usage control extends traditional access control techniques by allowing data providers to specify *provisions* and *obligations* [11]. Intuitively, provisions express the conditions that must be fulfilled in order to grant or deny an act [7]. For example, access to the profile of data provider A is granted only for accounting purposes. Obligations express events that must occur once an act is granted or denied. For example, data provider A wants to be notified whenever the collection of attributes via RFID readers take place.

Figure 2 depicts the core definition of our policy language in BNF-notation. Intuitively, the policy of a data provider A is a finite set of rules $P_A = \{r_1, \ldots, r_n\}$ (Line 1), each of which can stand for a (conditional) act, i.e. collection or access regulation (Lines 2 and 3). When formulating a collection rule, A stipulates whether a certain subject is able to collect an attribute and/or event (Line 4). The same applies for the formulation of access rules (Line 5). In both cases, the wildcard $*$ can be used to represent a whole class of, e.g., subjects or attributes. Conditions can include provisions and obligations (Line 7): provisions regard the role a

```
 1.  <Policy>     := (<Rule>) | (<Rule>), <Policy>
 2.  <Rule>       := <Col_Ctrl> | <Col_Ctrl>, if (<Cond>) |
 3.                  <Acc_Ctrl> | <Acc_Ctrl>, if (<Cond>)
 4.  <Col_Ctrl>   := <Perm>, <Subj>, <Obj>, <Event>
 5.  <Acc_Ctrl>   := <Perm>, <Subj>, <Obj>, <Right>
 6.  <Cond>       := <Atom_Cond> | <Atom_Cond> && <Cond>
 7.  <Atom_Cond>  := <Provision> | <Obligation>
 8.  <Provision>  := role <Op> <Role> | purpose <Op> <Purpose>  |
 9.                  <DataField> <Op> <Value>
10.  <Obligation> := delete <DataField>  <Temp_mod> [<Sanction>] |
11.                  notify <DataProvider> <Temp_mod> [<Sanction>]
12.  <Perm>       := allow | deny
13.  <Right>      := read | write | exec <Cmd>
14.  <Temp_mod>   := immediately | within <Nat_Number> days
15.  <Sanction>   := otherwise <String>
16.  <Op>         := > | < | >= | <= | == | !=
```

Fig. 2. Policy language for dynamic systems.

subject takes, as well as the purpose of the access or collection and the value of collected data fields serving as guards (Lines 8 and 9); obligations encompass the deletion of some attribute within a certain timeframe and the notification of individuals (Lines 10 and 11). Obligations may or may well not include sanctions that hold in case a particular obligation is not fulfilled (Line 15).

The actual value of terminals, such as `Obj` and `Subj` are application-dependent and omitted here for simplicity. (To this end, we have defined data models corresponding to our scenario.) To illustrate how formulated rules appear and exemplify their expressive power, in Fig. 3 we consider two rules for the data provider A. Rule r_1, stipulates that A grants read access to his attributes provided the accessing subject adopts the role "Marketing", the purpose is personalised service and the accessed attribute is deleted within 30 days. In the case of non-adherence, a compensation of \$100 is due. Rule r_2 prohibits the collection of data by RFID-readers.

4 Secure Logging and Log Views

Log data is a central source of information in computer systems. In contrast to other rather "static" files, such as text documents or spreadsheets, log files allow one to reconstruct the dynamics of a system, i.e. the course of events that led to some particular state. Hence, log files are a central

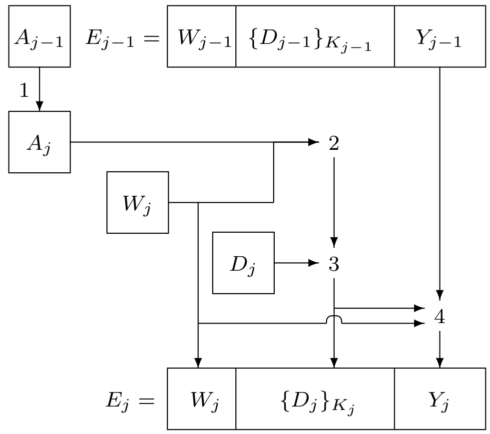


Fig. 4. Adding an entry to the log file.

encrypt log entries. Thus, we assume that the computation of the new value irretrievably overwrites the previous value.

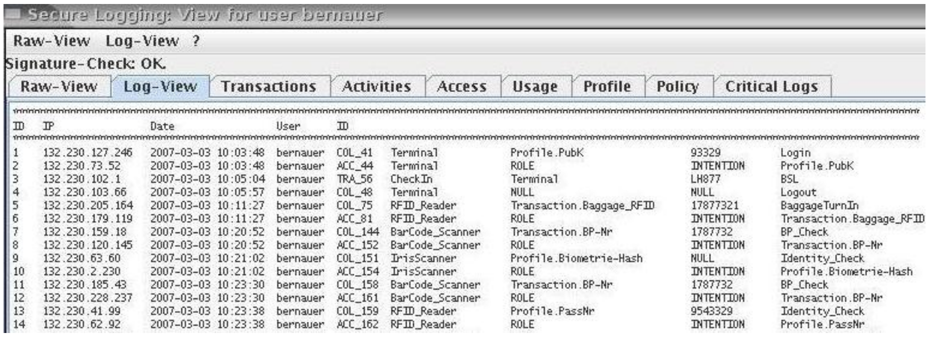
2. $K_j = Hash(W_j, A_j)$ is the cryptographic key with which the jth log entry is encrypted. This key is based on the index W_j, so that only corresponding data providers gain access to the entry.
3. $\{D_j\}_{K_j}$ is the encrypted log entry D_j.
4. $Y_j = Hash(Y_{j-1}, \{D_j\}_{K_j}, W_j)$ is the jth value of the hash chain. Each link of the hash chain is based on the corresponding encrypted value of the log data.

The generated log entry, denoted $E_j = W_j, \{D_j\}_{K_j}, Y_j$, consists of the index W_j, the encrypted log entry $\{D_j\}_{K_j}$, and the hash chain value Y_j.

4.1 Log Views and their Generation

A central concept to allow supervision is to furnish data providers with timestamped information regarding *which* attributes have been collected, *who* has had access to them and *how* collected attributes have been used. In our approach, these pieces of information are compiled into a *log view* [12], a concept bearing similarity with its homonymous counterpart in the field of databases.

Log views are individualised audit trails consisting of factual data (performed transactions, collected attributes, etc.) and monitored data (access and usage information) about a particular data provider, as well as meta data – in the form of a digital signature – about the generating



ID	IP	Date	User	ID				
1	132.230.127.246	2007-03-03 10:03:48	bernauer	COL_41	Terminal	Profile.PubK	93329	Login
2	132.230.73.52	2007-03-03 10:03:48	bernauer	ACC_44	Terminal	ROLE	INTENTION	Profile.PubK
3	132.230.102.1	2007-03-03 10:05:04	bernauer	TRA_56	CheckIn	Terminal	LH877	BSL
4	132.230.103.66	2007-03-03 10:05:57	bernauer	COL_48	Terminal	NULL	NULL	Logout
5	132.230.205.164	2007-03-03 10:11:27	bernauer	COL_75	RFID_Reader	Transaction.Baggage_RFID	17877321	BaggageTurnIn
6	132.230.179.119	2007-03-03 10:11:27	bernauer	ACC_81	RFID_Reader	ROLE	INTENTION	Transaction.Baggage_RFID
7	132.230.159.18	2007-03-03 10:20:52	bernauer	COL_144	BarCode_Scanner	Transaction.BP-Nr	1787732	BP_Check
8	132.230.120.145	2007-03-03 10:20:52	bernauer	ACC_152	BarCode_Scanner	ROLE	INTENTION	Transaction.BP-Nr
9	132.230.63.60	2007-03-03 10:21:02	bernauer	COL_151	IrisScanner	Profile.Biometrie-Hash	NULL	Identity_Check
10	132.230.2.230	2007-03-03 10:21:02	bernauer	ACC_154	IrisScanner	ROLE	INTENTION	Profile.Biometrie-Hash
11	132.230.185.43	2007-03-03 10:23:30	bernauer	COL_158	BarCode_Scanner	Transaction.BP-Nr	1787732	BP_Check
12	132.230.228.237	2007-03-03 10:23:30	bernauer	ACC_161	BarCode_Scanner	ROLE	INTENTION	Transaction.BP-Nr
13	132.230.41.99	2007-03-03 10:23:38	bernauer	COL_159	RFID_Reader	Profile.PassNr	9543329	Identity_Check
14	132.230.62.92	2007-03-03 10:23:38	bernauer	ACC_162	RFID_Reader	ROLE	INTENTION	Profile.PassNr

Fig. 5. Part of a log view for data provider `bernauer`.

data consumer and the integrity of a view. Figure 5 illustrates a part of log view of a data provider referred to as "bernauer".

As for the generation of log views, to retrieve a log view S_A the data provider A employs a trusted device (e.g. a home computer or a terminal dedicated to this purpose) to authenticate himself to the data consumer, who then starts a query over (possibly distributed) log files. Intuitively, the index of each entry is checked against the authenticated data provider. If they match and the entry passes an integrity check (based on the hash chain), then the content of the entry is decrypted and added to the log view of A. When all the entries are queried, the resultant view is signed and sent back to the inquiring data provider.

5 Automated Audits and Digital Privacy Evidence

Log views would, at least in theory, suffice to realise the holistic sense of control we argue for in this manuscript: data providers could browse through their log views and check whether their privacy policies have been adhered to or not. However, this is more intricate than it seems. Log views can easily include thousands of entries and their interrelationships are often hard to comprehend and reconstruct, regardless of how much effort we put into improving their readability.

We develop an approach to audit log views parameterised by the policies of data providers. Intuitively, given a policy $P := \{r_1, \ldots, r_n\}$ and a log view S, we define a transformation ν that takes P and returns the set of rules $V_P = \{v_1, \ldots, v_n\}$ such that each $v_i \in V$ denotes the violation of the corresponding rule r_i. To illustrate this, consider the rule r_2 in Fig. 3. By applying the transformation ν, the following violation is generated:

$v_2 :=$ `( allow, RFID-Reader, *, * )`.

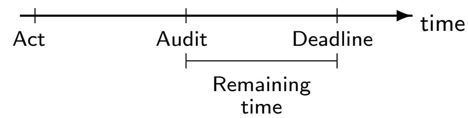


Fig. 6. Condition leading to an amber semaphore

This denotes that the collection of attributes through RFID readers is allowed, thereby contradicting the original desire of the data provider.

With V_P at hand, we then search for violations in the log view of the corresponding data provider. To this end, we define the pinpoint relation $\triangleright$ between views and the set of violations V_P such that $S \triangleright v_i$ if v_i can be pinpointed, i.e. detected, in S. If there is a $v_i \in V_P$ such that $S \triangleright v_i$, then there is an execution of the system that violates r_i and, in consequence, the policy P. In contrast, if there is no such v_i, such that $S \triangleright v_i$, then a violation of P can be ruled out. Technical details are found in [2].

We employ a semaphore notation to make the result of audit evident to the pertinent data provider. In this case, red obviously stands for a violation of some rule, while green denotes the compliance with a policy. An amber semaphore indicates that some obligation-based rule could not be pinpointed and therefore stands for a warning. Such a warning is triggered whenever a log view S is audited before the deadline of a pending obligation, as illustrated in Fig. 6.

A log view, together with the corresponding audit analysis, constitutes a privacy evidence. In the case of a violation, an individual may click over the semaphore and obtain details on which rules have been violated as well as the entries that led to this result. A similar procedure can be carried out when the semaphore shows amber.

6 Discussion and Perspectives

Taking stock, in this manuscript we purport the thesis that a holistic notion of control for IMS encompasses not only the regulation of communicated (respectively, collected) attributes, but also the supervision of adherence to stated policies. While this understanding of control as regulation and (at least the option of) supervision is prevalent in the common language, to our knowledge it has not been considered in the context of IMS. We firmly believe that the investigation of approaches to realise such forms of control is the next milestone towards the development of IMS to cope with the privacy challenges of dynamic systems.

portance of supervision as a distinguishing factor for future IMS and privacy-aware (dynamic) systems.

References

1. R. Accorsi. On the relationship of privacy and secure remote logging in dynamic systems. In S. Fischer-Hübner, K. Rannenberg, L. Yngström, and S. Lindskog, editors, *Proceedings of the 21st IFIP TC-11 International Security Conference: Security and Privacy in Dynamic Environments*, volume 201 of *International Federation for Information Processing*, pages 329–339. Springer-Verlag, 2006.
2. R. Accorsi and M. Bernauer. On privacy evidence for UbiComp environments – Broadening the notion of control to improve user acceptance. In A. Bajart, H. Muller, and T. Strang, editors, *Proceedings of the 5th Workshop on Privacy in UbiComp*, pages 433–438, 2007.
3. R. Accorsi and A. Hohl. Delegating secure logging in pervasive computing systems. In J. Clark, R. Paige, F. Pollack, and P. Brooke, editors, *Proceedings of the 3rd International Conference on Security in Pervasive Computing*, volume 3934 of *Lecture Notes in Computer Science*, pages 58–72. Springer Verlag, 2006.
4. M. Casassa-Mont, S. Pearson, and P. Bramhall. Towards accountable management of privacy and identity. In E. Snekkenes and D. Gollmann, editors, *Proceedings of the European Symposium on Research in Computer Security*, volume 2808 of *Lecture Notes in Computer Science*, pages 146–161. Springer-Verlag, 2003.
5. M. Froomkin. The death of privacy? *Stanford Law Review*, 52(5):1461–1543, May 2000.
6. A. Hohl. *Traceable Processing of Personal Data in Remote Services Using TCG*. PhD thesis, University of Freiburg, 2006.
7. S. Jajodia, M. Kudo, and V. Subrahmanian. Provisional authorizations. In A. Ghosh, editor, *E-Commerce Security and Privacy*, pages 133–159. Kluwer Academic Publishers, 2001.
8. E. Kenneally. Digital logs – Proof matters. *Digital Investigation*, 1(2):94–101, June 2004.
9. G. Müller. Privacy and security in highly dynamic systems. *Communications of the ACM*, 49(9):28–31, September 2006.
10. A. Pfitzmann. Multilateral security: Enabling technologies and their evaluation. In G. Müller, editor, *Proceedings of the International Conference on Emerging Trends in Information and Communication Security*, volume 3995 of *Lecture Notes in Computer Science*, pages 1–13. Springer-Verlag, 2006.
11. A. Pretschner, M. Hilty, and D. Basin. Distributed usage control. *Communications of the ACM*, 49(9):39–44, September 2006.
12. S. Sackmann, J. Strüker, and R. Accorsi. Personalization in privacy-aware highly dynamic systems. *Communications of the ACM*, 49(9):32–38, September 2006.
13. J. Strüker. Der gläserne Kunde im Supermarkt der Zukunft. *Wirtschaftsinformatik*, 49(1):59–62, January 2007.