

AN EXTENDED ANALYSIS OF DELEGATING OBLIGATIONS

Andreas Schaad

Abstract: In [1] we have presented our initial investigations into the delegation of obligations and the concept of review as one kind of organisational principle to control such delegation activities. However, this initial approach was too simplistic and failed to explain how a principal may be related to an obligation; how obligations relate to roles; and how the delegation of specific and general obligations may be controlled through the concepts of review and supervision. As a result, we presented a more detailed and refined analysis of organisational controls in the context of a formal framework [2]. This paper summarises some of our investigations.

1. INTRODUCTION

Organizational control principles, such as those expressed in the separation of duties, delegation of obligations, supervision and review, support the main business goals and activities of an organisation. A framework has been presented [2], in which organisational control principles can be formally expressed and analyzed using the Alloy specification language and its constraint analysis tools [3]. Specifically the delegation of obligations and arising review obligations have initially been treated in [1]. These earlier discussions were influenced by the case studies into the access control environment of a European bank [4], [5].

This paper attempts to provide a more detailed and refined analysis of review and supervision controls with a particular emphasis on the notion of general and specific obligations. This distinction will allow us to address conceptual gaps in our earlier work, namely, how a principal may be related to an obligation; how obligations relate to roles; and how the delegation of specific and general obligations may be controlled through the concepts of review and supervision.

The rest of this paper is structured as follows. Section 2 provides some background information on our established framework for control principles, expanding on the formal modeling of authorisations and obligations with an emphasis on general and specific obligations. Section 3 addresses the delegation of policy objects, in particular focusing on the delegation of general and specific obligations. Such delegation activities require to be controlled through review and supervision controls which are discussed in section 4.

2. A FRAMEWORK FOR ORGANISATIONAL CONTROL PRINCIPLES

The structure of the conceptual model [2] that we use as the basis for the specification, analysis and exploration of control principles is displayed in figure 1. Each box represents an object type which is called signature in Alloy and the open headed arrows represent type extension.

Objects can be members of Groups . A group is itself an object and may thus also be a member of some other group. A Principal is an object representing a human user or automated component in the system. A Policy Object is an abstract representation of a rule determining the behavior of principals in the system. A policy object is either an Authorization or an Obligation and can have subject and target object it applies to [6]. Policy objects may be related to a principal either directly or through a Role of which he is a member of, since policy objects may have principals or roles as their subject. Policy objects define Actions. In the case of obligations these are the actions that have to be performed and in case of authorisations the allowed actions. Execution of an action may create Evidence which is specified in an obligation such that it can be investigated whether the obligation was satisfactorily met.

A Review is a specific kind of obligation and results out of the previous delegation of an obligation. Review Actions are a specific kind of action and evidence is reviewed by them. Two role specific relations allow for the formation of role hierarchies and the definition of mutually exclusive roles. A Position is a specific kind of a role with some associated, context-dependent, attributes. Positions are part of an organisational command and control hierarchy and can form supervision hierarchies over the supervises relation.

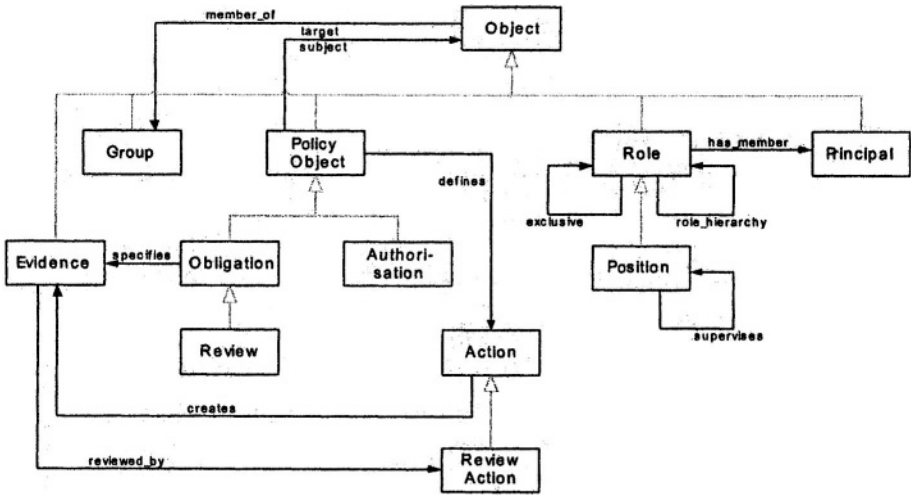


Figure 1: Graphical Abstraction of the Control Principle Framework

We used the Alloy language, based on a Z-like predicate logic, for our modeling purposes. Once a specification has been written and compiled in Alloy, it can be made subject to automated analysis and exploration using state-of-the-art satisfiability solvers [3].

2.1 Modeling policy objects

Within our control principle model, policy objects are either authorisations or obligations. Principals, or the roles of which principals are a member of, may be subject to these policy objects. In other words, a principal is related to a set of policy objects over the roles he holds or on the basis of a direct assignment. The target of a policy object defines the objects against which the actions of the policy are executed. In this context these subjects and targets are, however, expressed through explicit relations, and not in the form of domain expressions as in Ponder [6] since there is no formally defined domain model.

Authorisations state what a principal is permitted to do by using the actions defined by the authorisation. Authorisations can be shared between principals through roles or on the basis of direct assignments.

Obligation policies are an abstraction for defining the actions that must be performed by a principal on some target object when some specified event occurs. While this definition reflects our understanding of obligations, it requires a more detailed discussion on the requirements this raises with respect to the Alloy specification.

Alloy Specification 1: Example Alloy specification

```

//Definition of general signatures
disj sig Object{}
disj sig PolicyObject extends Object{}
disj sig Obligation extends Object{}
    sig Review extends Obligation{}
//Review signature is not defined as disjoint (Section 2.6)
...
//Definition of Obligation Instance Signature
disj sig ObligationInstance extends
    Obligation{}
...
//Objectification of State and definition of relationships
disj sig State {
s_has_instance:Obligation->ObligationInstance
s_specifies: Obligation -> Evidence
...}

```

To begin with, Alloy specifications are mainly concerned with structural properties and the possibilities to model dynamic behavior are limited to simple sequences of states, discussed in more depth in [3]. This means that there is no event architecture as in, for example [6] or [7], that would allow us to explicitly model triggering events. This, and the current representation of obligation policies does at this stage not allow us to clearly represent:

- What it means for a principal to hold an obligation;
- How obligations relate to roles.

2.2 Processing invoices: A motivating example

We consider a general obligation policy which specifies that clerks have to process customer orders. The defined event on which the obligation arises might in this case be the arrival of an order in the clerk's inbox. When this event occurs, the clerk now has the specific obligation to process this order. On the basis of this observation it seems natural to us to adopt the notion of general obligations that have specific obligations as their instances.

2.3 Obligations and roles

Our initial model [1], [8] was a simple structural model like RBAC96 [9], using roles as a convenient administrative shorthand over which to relate principals and policy objects. It did not allow us to describe situations such as the previous order processing example, and it was not clear how principals were related to obligations when roles are involved.

If a principal is member of a role, then he has the authorisations of that role at his discretion. Since several principals may be a member of the same role, this means that the same authorization applies to several principals.

This does not raise any conceptual difficulties. However, in the case of obligations this relationship requires further clarification as there initially seem to be two contradicting requirements. On the one hand it is desirable to specify an obligation that applies to several principals, and roles are the ideal structural means for doing so. On the other hand an obligation should be clearly related to one principal only, specifically when considering the delegation of obligations, such that:

1. It can be assessed who can be held to account;
2. The same actions are not performed twice.

2.4 General and specific obligations

The problems described in the previous section can be resolved on the basis of the general assumption of this model that a distinction must be made between general and specific obligations. This means that principals may have the same general obligation through a common role, but the specific instances of this general obligation must be directly related to exactly one principal. The sharing of specific obligations between principals is therefore excluded. To summarise, the following requirements and assumptions have been identified and discussed:

1. A distinction between general and specific obligation policies needs to be made.
2. General obligations may be shared between roles or principals, but a specific obligation must always be related uniquely to a principal.
3. The assumption is that specific obligations have been created based on some general obligations. However, there is no explicit architecture to model triggering events, their creation is outside the scope of this model.

2.5 Representing general and specific obligations in Alloy

We recall the previously given example of a clerk and his obligation to process incoming orders. Such a situation can be represented through the following conceptual model. We defined an explicit signature `ObligationInstance` related to the `Obligation` signature through a `has_instance` relation. While this adds another degree of complexity to the model, it now explicitly expresses the distinction between general and specific obligations. What is currently lost here, however, is that such specific obligations are also obligations, i.e. the facts specified for policy objects and general obligations should also apply for them.

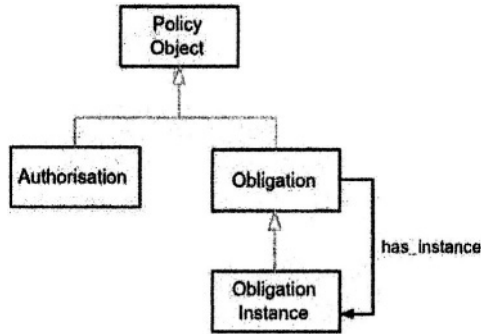


Figure 2: Modeling Obligation Instances

This is easy to resolve by extending the specific obligation instance from the general obligation. The extension also explains why such specific obligation instances must not be confused with the object-oriented notion of class instances. In this context general obligations and their instances are distinct signatures with distinct properties. This conceptualization is part of the Alloy specification 1, with the corresponding graphical representation being displayed in figure 2. From now on when talking about general obligations we refer to the obligation signature, while specific obligations refer to the ObligationInstance signature. There are now some constraints that need to be specified in order to clarify this proposed extension and satisfy the previously elicited requirements.

It has been said that obligations should be carried out by one principal. This requirement must now be refined to distinguish between general obligations and obligation instances. An obligation instance must always relate to exactly one principal: Shared obligations are forbidden.

Alloy Fact 1: *An obligation instance must always relate to exactly one principal.*

```
fact {all s:State | all obl:ObligationInstance|
  one(obl.(s.s_subject) & Principal)} //& set intersection operator
```

We further define that a specific obligation must always be the instance of one general obligation.

Alloy Fact 2: *An obligation instance has always one general obligation.*

```
fact {all s:State | all o: ObligationInstance|
  one ((s.s_has_instance).o & // - is the set difference operator
  (Obligation - ObligationInstance))}
```

It must also be the case that if a principal has a specific obligation, then this must be the instance of a general obligation he has through one of his roles or is a direct subject of.

Alloy Fact 3: *Every specific obligation a principal holds must be an instance of a general obligation he is a subject of through one of his roles or directly.*

```
fact {all s:State|all disj p1:Principal|all o: ObligationInstance |
  some o & (s.s_subject).p1 => // implication
  (s.s_has_instance).o in (s.s_subject).p1 || //or
  (s.s_has_instance).o in (s.s_subject).((s.s_has_member).p1)}
```

Finally, we define that a general obligation may only be directly assigned to a principal or to one of his roles but not to both. The reasons for this are mainly related to the performance of our later analysis, but we also think that any dual assignment does not make sense within an organisational context.

Alloy Fact 4: *A general obligation can only have a principal or one of his roles as a subject, but not both.*

```
fact {all s:State | all p1:Principal |
  all o:Obligation - ObligationInstance |
  some p1 & o.(s.s_subject) =>
  no o & (s.s_subject).((s.s_has_member).p1)}
```

2.6 Review and evidence

When an obligation is delegated, it may be made subject to a review obligation. The specific reasons and organisational motivations for this will be discussed in more detail in section 4.1. This section only concentrates on the basic structural properties required to support such delegation activities.

A review is defined as a specific type of obligation by using the object extension keyword for the Review signature as indicated in figure 1. It has a previously delegated obligation as its target through the target relation of the PolicyObject it is extended from. Evidence determines what the later discharge of such a delegated obligation has to produce to convince the delegator that the obligation has indeed been performed. At this level, evidence serves as an abstraction for what eventually has to be produced, but not that it has been produced. The later would require a notion of discharging and enforcing obligations (compare, for example, [10]), which is not part of this framework. Evidence is reviewed by the specific actions of the review that has the obligation specifying the evidence as its target. This is reflected in the design decision to extend specific review actions from a general action as shown in figure 1. The natural question to ask is how this concept of a review integrates with the definitions made in the previous section 2.4 that considers the distinction between general and specific obligations. Alloy does not initially assume that an extended signature is disjoint from the

signature from which it is extended. This is used as a convenient way of capturing that there may also be general and specific review obligations. Not having defined a review to be disjoint in the Alloy specification 1, a review may thus assume the type of an *Obligation* or *ObligationInstance*.

What are the effects of these assumptions? It must have been defined earlier how a review is performed. 'Earlier' in this case means that at the time a general obligation is assigned, the corresponding general review is assigned in parallel if delegation and review have to be supported. Thus, when an obligation instance is delegated, a review instance is created on the basis of the corresponding general review obligation. This instance now defines what review actions have to be performed on some evidence. As a result, the review may generate some evidence as well.

3. DELEGATION

Delegation may be used as a term for describing how duties and the required authority propagate through an organisation, usually in terms of the refinement of a high-level organisational goal into manageable policies which eventually lead to the execution of some task [11], [12]. This is often referred to as decentralisation or Management by Delegation [13] where delegation considers the passing of policy objects from one principal to another with respect to the performance of some activity and attainment of some common organisational goal. Delegation as a means for the distribution of work is thus one means of creating organizational structure.

However, often the term delegation is also used to describe how a principal passes some specific policy object on to some other principal, because the current structure does not allow the achievement of a goal one or both of these principals have [14]. If such delegation activities occur frequently, have a regular pattern or principals delegate some object indefinitely, then this indicates that the current organisational structure and procedures do not reflect the goals of the involved principals. An initially temporary and ad-hoc delegation must now become part of the regular administrative delegation activities shaping the formal organisational structure. There may be different factors motivating such general administrative delegation or ad-hoc delegation between specific principals.

We thus distinguish between two types of delegation that need to be clarified:

- Administrative delegation (administration); and
- Ad-hoc delegation (delegation)

This distinction is often not made clear, e.g. [15]. Both cause some sort of policy object assignment to be changed, where administration has a high degree of similarity, regularity and repeatability, and conversely ad-hoc delegation has a low degree of these. We argue that delegation may be seen as distinct from administration. Three characteristics can be used to support this distinction. These are the representation of the authority to delegate; the specific relation of a principal to an object; and the duration of this relation. Our work in [2] uses these for an in-depth comparison of existing models for delegation from the policy and role-based access control community.

3.1 Delegating authorisations

When explicitly delegating an authorisation policy object, several possible assignments of this policy object can be observed with respect to the two involved principals before and after the delegation. In particular, the following two (in)direct assignments of an authorisation policy to a principal drive this discussion:

1. Some delegated authorisation may be held by some delegating principal p_1 directly and through a role before the delegation.
2. Some delegated authorisation may be held by some delegating principal p_1 only through a role before the delegation.

With respect to the first point, the simultaneous assignment of a policy object to a principal and a role needs to be questioned with respect to authorisations. For example, if we consider a principal holding an authorisation both directly and through one of his roles, and the role is used as the basis for delegation, then the result may be that the direct assignment to the authorisation is removed for the principal. Vice versa, if the direct assignment is used as the basis for delegation and the principal should lose the authorisation, then he would still have it through his role.

A problem arises, if the authorisation was delegated on the basis of role membership. It cannot be simply removed from the role as this would propagate to all other possible occupants of that role, or may imply a change to the `s_has_member` relation which is considered to be outside the scope of delegation. Solutions such as the direct assignment of a negative authorisation [16], or creation of a new role with all but the delegated authorisation and the subsequent re-assignments, are not feasible within the context of this framework.

3.2 Delegating obligations

It now needs to be explored whether the delegation of obligations can be treated in a similar manner as the delegation of authorisations, focusing on our abstraction of general and specific obligations. This requires us to recall some of the previously specified constraints on obligations:

- A specific obligation instance must always be held by exactly one principal as defined in fact 1;
- The specific obligation of a principal must correspond to a general obligation he holds directly or through a role as defined in fact 2 and 3.
- A general obligation may be shared between two principals, either directly, through roles or both, but it may not be held by a principal directly and through a role as defined in fact 4.

Accordingly, if a principal decides to delegate an obligation, then this may refer to a general or specific obligation. A single delegation function can be used to delegate both types of obligation [2].

3.2.1 Delegating specific obligations

While so far no explicit assumptions had to be made about the status of the receiving principal with respect to the delegated object, the delegation of a specific obligation now requires the receiving principal to already hold the corresponding general obligation. In other words, a specific obligation can only be delegated between principals with the same general obligation. A principal should not be delegated a task he is not meant to do. The cardinality constraint in fact 1 for the delegated obligation instance and involved principals further restricts the possible delegation scenarios. Either the delegating principal holds the obligation or not and so does or does not the receiving principal.

3.2.2 Delegating general obligations

The delegation of a general obligation requires some additional constraints that need to be considered. More specifically, these constraints concern whether the general obligation is assigned to a role of the delegating principal or directly to him, and what should be done with any currently existing specific obligations for that general obligation.

If role membership is the basis for the delegation, then we may observe that the delegating principal must retain the general delegation. In case of the obligation being delegated on the basis of a direct assignment, the delegating principal may also choose to drop the obligation if there are no existing

instances. However, since there may be existing instances for a general obligation, it needs to be decided what to do with these after the delegation. A principal may choose to delegate all, some or none of any existing instances together with the general obligation. All these possible delegation scenarios have been formally captured in [2] and we can summarise that:

1. If a delegated general obligation gob has some instances with some delegating principal $p1$ as its subject then it may be the case that:
 - a) the delegating principal $p1$ retains gob and some receiving principal $p2$ obtains it; at the same time all, some or none of the existing instances are delegated or that;
 - b) the delegating principal $p1$ loses gob and $p2$ obtains it; at the same time all of the existing instances are delegated.
2. If a delegated general obligation gob has no instances, then it may be the case that some delegating principal $p1$ retains or loses gob , while the receiving principal $p2$ obtains it.

4. REVIEW AND SUPERVISION

In the previous chapter we have described the delegation of policy objects. We investigated the delegation of obligation policies which required us to make a distinction between the delegation of specific obligation instances and the delegation of general obligations. These two forms of delegating obligations raise concerns about how control may be retained over a delegated obligation by the delegating principal. In this section we discuss the two control principles of review and supervision to address this.

4.1 The concept of review and its organisational motivations

Obligations are continuously created, delegated, revoked or discharged according to the overall goals of an organisation and the general principle of distributing work. Ideally, there should never be any uncertainty about who currently holds an obligation, whether somebody has discharged his obligations, the effect of such a discharge, and who has to ultimately ensure that the tasks of an obligation are performed. In order for them to be able to give an account of the obligation that they have delegated, they must review it. We propose that this may be done by creating a review policy referring to the delegated obligation. In this context, review is understood as an obligation referring to a previously delegated obligation which has to examine the results of the discharge of this delegated obligation. The holder

of such a review policy has then to make sure that the obligation he delegated has been carried out satisfactorily.

A review does not act as a direct enforcement mechanisms for the delegated obligation, but as a post-hoc control and detective mechanism. If the review fails because the delegated obligation has not been discharged this may trigger corrective measures to be taken. In [17] a distinction between procedural and output controls is made as the components of administrative controls. We argue that review conforms to both these definitions of control. On the one hand the creation of a review is part of the delegation procedure for certain obligations, while on the other hand this review then controls the output of the discharge of a delegated obligation.

4.1.1 Reviewing delegated obligations - A motivating example

A review policy is the obligation of a principal to investigate the state of affairs of an obligation he delegated to another principal. In other words, a review is an obligation on an obligation, where some defined review actions provide the application specific information on how to perform the review.

We can imagine an obligation policy for Jon to prepare the quarterly sales report. On the 1st of May Jon must prepare the report by performing the required actions with the sales database being the target. Current business requires Jon to delegate this obligation to Clara. We assume that Clara is equally qualified and authorised to do this. In his role as the delegator, Jon now has to review that Clara carried this task out satisfactorily before the deadline. This is done by defining evidence that has to be generated by Clara when discharging the delegated obligation, as well as the review actions that are used to review this evidence. This evidence may be the actual `Sales_Report_1stQ` that is generated, and we assume that there are some defined tuples to relate this evidence to the actions of the review. Jon can now discharge his review obligation by viewing the sales report Clara generated when discharging the obligation Jon had delegated to her.

4.1.2 Expressing review controls

A review policy is created as the result of delegating an obligation and is a specific type of obligation itself. This specialisation relationship between an obligation and a review obligation has been modelled using Alloy's extension mechanism as described in figure 1 and corresponding Alloy specification 1.

4.1.3 General and specific review obligations

We have explored the basic concepts of reviewing delegated obligations in the previous sections. Now it needs to be investigated how these results fit into our abstraction of general and specific obligations to resolve the problem of assigning roles and obligations.

However, before doing so we must first assess how far a review obligation itself has to adhere to this abstraction. Since a review is an obligation, the distinction between general and specific obligations must also apply to it. The implication is that any specific review obligation has a general review obligation of which it is an instance. This further means that a principal must have a general obligation to review for any of his particular review instances. What should be the relationship between this general review obligation and some delegated obligation instance that is to be reviewed? There is no direct relationship. However, the general review obligation should have the general obligation, of which any obligation to be reviewed is an instance, as its target. A review instance can only have some other obligation instance as a target if the same is true for their respective general obligations. This implies that this general review obligation was already held by the delegating principal before the delegation, or was created at the time of delegation.

4.2 The concept of supervision and its organisational motivations

Obligations are delegated in order to facilitate the distribution of work. In the previous sections we discussed the delegation of obligations and the supporting concept of review, distinguishing between the delegation of specific obligation instances and the delegation of general obligations.

The first kind of delegation is what we considered as an ad-hoc form of delegation, allowing individual principals to distribute obligations more efficiently. In this section we investigate the delegation of general obligations as a management activity with the aim of creating a more permanent form of organisational structure through the distribution of work. We believe that the concept of supervision is a control principle that supports this form of delegation.

The distribution of work through delegation mechanisms requires the observation and direction of the execution of any delegated task. We recall the observations we made in section 3.2.2 on the delegation of a general obligation and the consequences this may have. There we discussed that the principal who delegated a general obligation should still be held accountable for his delegation, not only with respect to any existing obligation instances

that may have consequently been delegated, but also any possible future obligation instances that may arise for a principal on the basis of this delegation. We propose to capture this accountability for a delegated general obligation in the form of a supervision control.

We define supervision as the general obligation of a principal occupying a position to review the obligations of principals in supervised positions. This supervision relationship is the result of some prior delegation of general obligations.

4.2.1 Supervising delegated obligations - A motivating example

The concept of supervision builds upon our earlier established concept of review with similar underlying organisational motivations. The supervision relation between positions has little meaning by itself, unless there are some supporting review obligations. This is illustrated in the following example.

We consider a company in which a principal Jon processes outgoing shipments. The company grows and with it the amount of shipments. Soon, Jon is not able to handle this task anymore. Two new employees Clara and Bill are hired. Jon now delegates his obligation to process shipments to these two new employees. More precisely, positions are created to handle the growth of the organisation, and Jon in his new position as a Senior Shipment Manager delegates the general obligation to process shipments to the position Junior Shipment Manager occupied by the two new employees. The Senior Shipment Manager position supervises the Junior Shipment Manager position. This means that through his position, Jon has an obligation to review that Bill and Clara process shipments correctly. In this case Jon might have to review the dispatch of every shipment 48 hours after the initial order.

4.2.2 Expressing supervision controls

We defined supervision as the general obligation of a principal occupying a position to review the obligations of principals in supervised positions. This supervision relationship is the result of some prior delegation of general obligations. The supervises relationship expresses this supervision. This relationship alone is not enough to satisfy our definition of supervision as the general obligation to review and [2] provides an extended discussion.

5. SUMMARY AND CONCLUSION

We have provided a detailed analysis of review and supervision controls with a particular emphasis on the notion of general and specific obligations. This distinction allows us to explain how a principal may be related to an obligation; how obligations relate to roles; and how the delegation of specific obligation instances and general obligations may be controlled.

This first kind of delegation is what we considered as an ad-hoc form of delegation, allowing individual principals to distribute obligation instances. A review policy is created as the result of delegating such an obligation. A review is a specific type of obligation with a delegated obligation as its target. The second kind of delegation is a management activity with the aim of creating a more permanent form of organisational structure through the distribution of work. Supervision is defined as the general obligation of a principal occupying a position to review the obligations of principals in supervised positions, assuming that at some prior stage these reviewed obligations have been delegated between those positions.

We are currently exploring how these concepts and controls may now be implemented and integrated into a legal workflow environment within, the EU eJustice project. This will require us to further clarify how general obligations are created, authorisations are methodically derived and how evidence can be defined and reviewed without creating organizational bottlenecks. Additionally, the declarative revocation mechanisms defined in [2] now need to be implemented.

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