Model-Driven Specification and Design-Level Analysis of XACML Policies

Hanine Tout, Azzam Mourad
Department of Computer Science and Mathematics
Lebanese American University
Beirut, Lebanon
Email: {hanine.tout, azzam.mourad}@lau.edu.lb

Chamseddine Talhi
Department of Software Engineering and IT
École de Technologie Supérieure
Montreal, Canada
Email: chamseddine.talhi@etsmtl.ca

Hadi Otork
Department of Computer Engineering
Khalifa University
Abu Dhabi, UAE
Email: hadi.otrok@kustar.ac.ae

Hamdi Yahyaoui
Department of Computer Science
Kuwait University
Safat, Kuwait
Email: hamdi@sci.kuniv.edu.kw

***Abstract*—Throughout the recent years, Web services security has been the target of many researchers. Particularly, by integrating policies and rules to govern the Web services behaviors at runtime, researchers have been able to prove the capability of policy languages in enforcing Web services security. XACML or eXtensible Access Control Markup Language is one of the most widely adopted security standards for controlling access to individual and between composed services based on policies specifications. However, like any other policy language, XACML policies are specified in structural files with complex syntax, which makes the policies specification process both, time consuming and error prone. Moreover, security policies are commonly verified in an afterthought stage after their enforcement, yet with diversity of rules and conditions specified in the policies, hidden conflicts, redundancies and access flaws are more likely to arise, which expose the system to serious vulnerabilities at execution time. To address these problems, we propose in this paper a new approach that allows high-level specification of XACML security policies and provides design-level analysis to detect problems and vulnerabilities in the policies semantics, a priori to their integration and execution in the system.**

***Index terms*—Web Services Security, XACML, Security Policies, Model-Driven Specification, Design-Level Analysis**

I. Introduction

Managing Web services security by policies enforcement has become one of the most active research areas. XACML [1] or eXtensible Access Control Markup Language is one of the most widely adopted security standards for controlling access to individual and between composed services based on policies specifications. However, like any other policy language, XACML policies are specified in structured files of too low and complex syntax, which makes them hard to be used by wide spectrum of users who are accustomed to work with abstract architectural system models. In addition, this also makes the policies definition process time consuming, and foremost error-prone, especially when combining many policies, rules and conditions to govern the system. In this context, several researchers [2, 3, 4] have proposed UML profiles to offer high-level graphical modeling approach for policies specification. UML profile [5] is one of the UML extension mechanisms that allows UML models to be customized for specific domains, and these approaches have proved its capabilities to define different access control models. Yet, the proposed profiles in these approaches [3, 4] do not cover all the elements of XACML policies and most importantly, they rely on XACML 2.0, which is not the latest version of XACML.

Moreover, with diversity of rules and conditions specified in complex policies, hidden conflicts, redundancies and access flaws are more likely to arise. A conflict between two policy rules arises when they are defined in a way that one of them grants access and the other denies access for the same set of subject(s), resource(s) and action(s). Whereas, two policy rules are redundant when they are defined for the same set of subject(s), resource(s), action(s) and the same set of conditions, with same effect (i.e., deny or permit). Finally, access flaws are badly defined rules and/or policies which allow users to gain accidental access to particular resources. An afterthought analysis of policies after their integration, increases the possibility to propagate these issues through the system deployment where locating and resolving them will be impossible. In this context, different approaches [6, 7, 8] have proposed analysis mechanisms for XACML policies. Yet, these approaches miss important elements in XACML, disregard some of these serious issues, and more importantly none of the proposed analysis mechanisms is applied at the design level, where only the evaluation of policies has been presented [9, 10].

To address all these problems, we present in this paper a new approach that consists of UML profile to allow high-level, straightforward, visualized specification of standard XACML policies conforming with the latest language version, and design-level analysis to detect problems like conflicts and redundancies and other vulnerabilities as access flaws in the policies semantics, at design level, a priori to their integration and execution in the system.

The main contributions of this work are twofold:

- UML profile for XACML to provide high-level specification of security policies.

- Design-level analysis to detect problems and vulnerabilities like conflicts, redundancies, and access flaws in the policies semantics.

The rest of the paper is organized as follows. Section II presents an overview about the proposed approach architecture, illustrates the proposed UML profile and introduces the design-level analysis of policies semantics. Section III demonstrates the feasibility and efficiency of our proposition through a case study. In Section IV, we discuss existing relevant works in the literature to distinguish and shed the light on our contributions. Finally, in Section V, we conclude the paper and draw some future research directions.

II. Proposed Approach

The proposed approach architecture is depicted in Figure 1. We introduce first a UML profile for high-level policies specification of policies, as an alternative to the XML-structured files of XACML. The proposed profile captures all the elements of the latest version of this language (i.e., Policy set, policy, rule, target, combining algorithms, condition, obligation and advice). To specify security policies, users create a UML model and then apply the proposed profile on it by attaching stereotypes, parameterized by tagged values, to the UML elements in the model (M). Using our XACML model to sets converter, the corresponding sets are generated then conveyed to the analyzer. In the latter, we implement algorithms capable of detecting problems and vulnerabilities like conflicts, redundancies and access flaws in the policies semantics at the model level, preventing the integration of such problems in the system at runtime. The analyzer generates a detailed report indicating the problems in case any of them exists, and locating the policies and rules behind them.

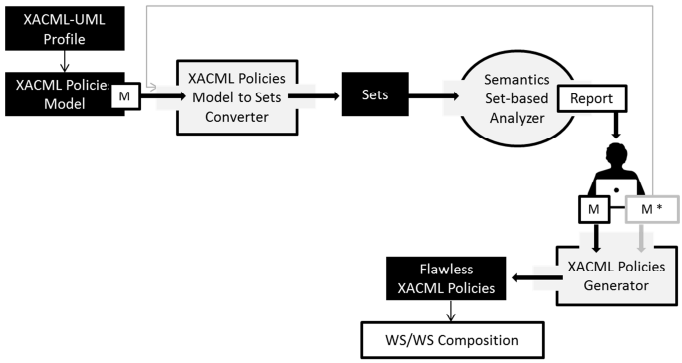


Fig. 1: Approach Architecture

Based on the report, the user updates the model (M*) for re-analysis. Once the policies model is proved to be flawless, its corresponding XACML code can be automatically generated using our XACML generator, and finally flawless policies can be applied on to control access whether to individual Web services or even to Web services composition. It's worth mentioning that since the detection is done at the design level, i.e., offline, before the policies enforcement and Web services execution, the proposed analysis do not entail any overhead at runtime.

A. UML Profile for XACML Policies Specification

In the sequel, we interpret the elements of our proposed profile illustrated in Figure 2. To remove any ambiguity, we used as much as possible the same names of the elements in the XACML language. We define the appropriate stereotypes, tagged definitions, operations and enumerations to cover all the elements of the latest version of XACML 3.0 that includes new elements and definition capabilities over its predecessor. A `PolicySet`, which extends the Metaclass `Class`, is a container of one or many `Policies`, and has an identifier `ID`, a policy proceeding order `PPO` that determines the order between these policies, and one of the policies combining algorithms `PCA` (i.e., Permit-overrides, Deny-overrides, Fisrt-applicable, Only-one-applicable). These algorithms are used in XACML to resolve decision application problems between policies.

Having its own identifier `ID`, a `Policy`, may include many `Rules` with precedence order among them `RPO` and one of the rule combining algorithms `RCA` (i.e., Permit-overrides, Deny-overrides, Fisrt-applicable) to resolve decision problems between its rules. Each rule can has a `Condition`, which is a function that should be validated before applying the rule.

`PolicySet`, `Policy`, and `Rule` can be all associated with `Targets`, `Obligations` and `Advices`. A `Target` identifies the action that a subject can exercise on certain resource, where in our case the action is an invoke and the resource is a service offered by partner Web service. The `Obligation` is a an action to be taken `Operation(params)` when certain trigger condition `TriggerCond` is met, which is the rule effect (i.e., Permit or Deny). Finally, the `Advice` is an analogous `Obligation`, yet its common use is to explain why someone was denied access to certain resource.

B. Design-Level Analysis of XACML Policies

Before starting the analysis, the XACML model to sets generator takes the policies UML model defined by the user after applying the proposed profile, then parses the elements in the model and generates the appropriate sets. These sets form the input to the analysis algorithms capable of detecting conflicts, access flaws and redundancies in the design model. They are defined as follows:

$$PS=\{ID,\ SOP,\ PPO,\ PCA,\ OBLs,\ ADs,\ TAR\}$$

The first generated set is the policy set *PS*, it includes its identifier *ID*, references to the set of policies it contains *SOP*, the order between the policies *PPO*, the combing algorithm *PCA*, sets of obligations *OBLs* and Advices *ADs* if any, and finally the target *TAR* defined as another set of subject *S*, resource *RES* and action *A*.

$$TAR=\{S,RES,A\}$$

Next, the policy set is generated. Other than the policy *ID*, this set includes references to the set of corresponding rules *SOR*, precedence order between them *RPO*, combining algorithm *RCA*, sets of obligations *OBLs* and Advices *ADs* if any, and the target *TAR*.

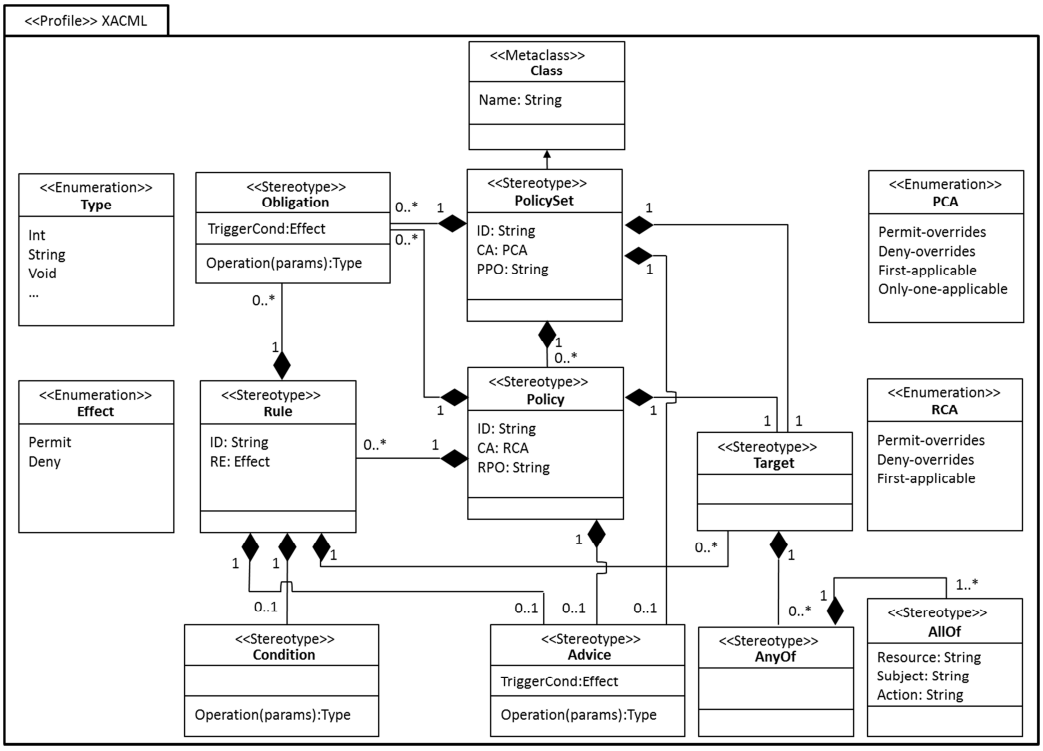


Fig. 2: XACML-UML Profile

$$P=\{ID,\ SOR,\ RPO,\ RCA,\ OBLs,\ ADs,\ TAR\}$$

Finally comes the rule set *R*, which includes *ID*, condition *C*, sets of obligations *OBLs* and Advices *ADs* if any, target *TAR*, and rule effect *E*.

$$R=\{ID,\ C,\ OBLs,\ ADs,\ TAR,\ E\}$$

C is a function to be evaluated against the target elements (i.e., subject, resource and action), which is defined as

$$C=\{Operation,\{params\}\}$$

Both *OBLs* and *ADs* are defined in the same way.

The analysis is done at three levels; rule-based analysis in Algorithm 1, policy-based analysis in Algorithm 2 and policy set-based analysis in Algorithm 3. Starting with Algorithm 1. To detect It takes existing conflicts, access flaws and redundancies between two rules R1 and R2, the algorithm compares their targets, conditions and effects. If the target (i.e., Subject, Resource and Action) and condition set of R1 are subset of those of R2 (Lines 1 and 2), both rules have the same effect (Line 3), then R1 is causing access control flaw. If R1 target intersects with R2 target (Lines 9 and 10) and both rules have opposite effects (Line 11), then they are conflicting. Otherwise, with same effects the rules are redundant. Finally, if none of the problems is found, an empty set is returned.

Next, Algorithm 2 analyzes the policies. It provides a set of all problems (i.e., access flaws FPS, conflicts CPS and redundancies RPS) that exist between two policies P1 and P2. The first part of the algorithm (Line 1 till 16) checks for flaws, conflicts and redundancies within each policy, while in the second part (Line 17 till 37), this checking is conducted between rules from different policies. The returned values of Algorithm 1 are appended to the appropriate sets in Algorithm 2.

Algorithm 1 Rule_Based_Analysis($R1$, $R2$)

Input : Two Rules R1 with Target TAR1 = {S1,RES1,A1}, condition C1, Effect E1 and R2 with Target TAR2 = {S2,RES2,A2}, condition C2, effect E2
Output : Rule analysis ∈ {Flaw, Conflict, Redundant or Null}

1: **if** $(S2 \subseteq S1) \wedge (RES2 \subseteq RES1) \wedge (A2 \subseteq A1)$ **then**
2: **if** $(C2 \subseteq C1)$ **then**
3: **if** (E1 = E2) **then**
4: // R2 is a subset of R1
5: **return** "Flaw";
6: **end if**
7: **end if**
8: **end if**
9: **if** $((S1 \cap S2) \neq \emptyset) \wedge ((RES1 \cap RES2) \neq \emptyset) \wedge ((A1 \cap A2) \neq \emptyset)$ **then**
10: **if** $((C1 \cap C2) \neq \emptyset)$ **then**
11: **if** (E1 $\neq$ E2) **then**
12: **return** "Conflict";
13: **else**
14: **return** "Redundant";
15: **end if**
16: **end if**
17: **end if**
18: **return** ;

Finally, Algorithm 3 analyzes the policy sets. This algorithm displays all access flaws, conflicts and redundancies

Algorithm 2 Policy_Based_Analysis($P1$, $P2$)

Input : Policy P1 with Target TAR1 = {S1,RES1,A1} and P2 with Target TAR2 = {S2,RES2,A2}
Output : Flaw Problem Set FPS, Conflict Problem Set CPS and Redundancy Problem Set RPS

1: //Check rules in each policy
2: **for** $l := 1$ *to* 2 **do**
3: **for** $i := 1$ *to* $P_{lNumberofRules-1}$ **do**
4: **for** $j := 2$ *to* $P_{lNumberofRules}$ **do**
5: **if** (RULE_BASED_ANALYSIS(R_{li}, R_{lj}) = "Flaw") **then**
6: FPS = FPS $\cup$ $Flaw_{R_{li},R_{lj}}$;
7: **end if**
8: **if** (RULE_BASED_ANALYSIS(R_{li}, R_{lj}) = "Redundant") **then**
9: RPS = RPS $\cup$ $Redundant_{R_{li},R_{lj}}$;
10: **end if**
11: **if** (RULE_BASED_ANALYSIS(R_{li}, R_{lj}) = "Conflict") **then**
12: CPS = CPS $\cup$ $Conflict_{R_{li},R_{lj}}$;
13: **end if**
14: **end for**
15: **end for**
16: **end for**
17: //Check rules in both P1 and P2
18: **if** ($RCA_{P1} = RCA_{P2}$) **then**
19: **if** ((($S1 \cap S2$) $\neq \emptyset$) $\wedge$ (($RES1 \cap RES2$) $\neq \emptyset$) $\wedge$ (($A1 \cap A2$) $\neq \emptyset$)) **then**
20: **for** $l := 1$ *to* $P1\_{NumberofRules}$ **do**
21: **for** $m := 1$ *to* $P2\_{NumberofRules}$ **do**
22: **if** (RULE_BASED_ANALYSIS(R_l, R_m)= "Flaw") **then**
23: FPS = FPS $\cup$ $Flaw_{R_l,R_m}$;
24: FPS = FPS $\cup$ $Flaw_{P_1,P_2}$;
25: **end if**
26: **if** (RULE_BASED_ANALYSIS(R_l, R_m) = "Conflict") **then**
27: CPS = CPS $\cup$ $Conflict_{R_l,R_m}$;
28: CPS = CPS $\cup$ $Conflict_{P_1,P_2}$;
29: **end if**
30: **if** (RULE_BASED_ANALYSIS(R_l, R_m) = "Redundant") **then**
31: RPS = RPS $\cup$ $Redundant_{R_l,R_m}$;
32: RPS = RPS $\cup$ $Redundant_{P_1,P_2}$;
33: **end if**
34: **end for**
35: **end for**
36: **end if**
37: **end if**
38: **return** ;

Algorithm 3 PolicySet_Based_Analysis(PS)

Input : A Policy Set PS
Output : Analysis report

1: Global FPS = $\emptyset$;RPS = $\emptyset$;CPS = $\emptyset$;
2: **for** $i := 1$ *to* $PS_{NumberofPolices-1}$ **do**
3: **for** $j := i + 1$ *to* $PS_{NumberofPolices}$ **do**
4: PA = POLICY_BASED_ANALYSIS(P_i, P_j);
5: **end for**
6: **end for**

between policies and rules existing within a policy set PS. It initializes the corresponding global sets FPS, CPS and RPS (Line 1) and calls Algorithm 2 (Line 2 till 6) for checking flaws, conflicts and redundancies within each policy and between policies and subsequently append the relevant sets.

III. CASE STUDY

To better illustrate our approach, we suggest a Flight System (FS) as a running example. The system consists of a composition of three partners Web services. First, a Financial Data WS, which offers access to financial reports. Second, Flight Inquiries WS that displays the flights with their schedules, available seats and comparable tickets prices, according to the user preferences. Third, a Reservation WS that offers the ability to book a flight ticket.

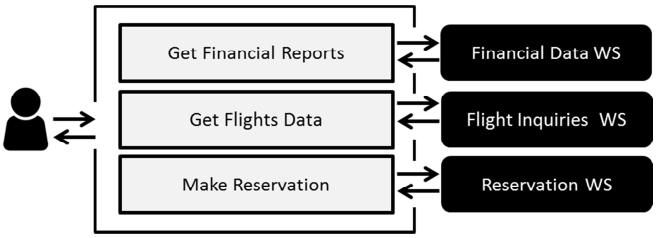


Fig. 3: Flight System (FS)

To enforce security, The system imposes many policies and rules that can be defined in an XACML file. Figure 4 depicts such XACML policy set reflecting the complexity in the policies definition. The policy set consists of two policies P1 and P2 and has a permit-overrides combining algorithm. P1 defines two rules R1 and R2. R1 gives only admin the permission to access the financial data while R2 permits anyone to access the same resource. On the other hand, P2 defines two other rules R3 and R4. R3 allows anyone to make reservation in the flight agency system while R4 prevents anyone from making reservation in particular period. Figure 4 shows clearly that specifying security policies in regular XACML XML-based format is subtle and time consuming, and even the analysis of such format is complex. To recall, XACML provides only an evaluation engine at runtime, yet does not have any efficient mechanism to detect problems and vulnerabilities such as conflicts, redundancies and access flaws between policies and rules.

A. Model-Driven Security Policies Specification

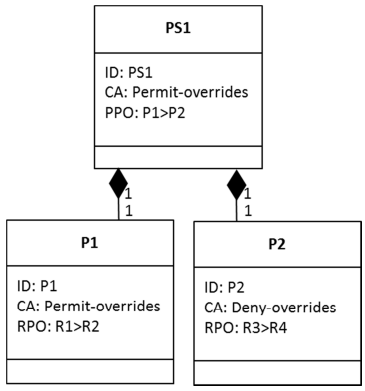
Rather than writing this long, verbose and complex XACML policy set for the Flight System, following our approach, the user can create a simple UML model that contains: Policy set PS1, Policies P1 and P2, Rules R1, R2, R3 and R4, Conditions C1 and C2, and Targets for each rule (along with their subelements) then applies systematic transformation on the model based on the proposed UML profile. This is done by:

1) Applying `PolicySet` stereotype on `PS1` and specifying its tagged values `ID`, `CA` and `PPO`.
2) Applying `Policy` stereotype on `P1` and `P2` and specifying their tagged values `ID`, `CA` and `RPO`.
3) Applying `Rule` stereotype on `R1`, `R2`, `R3` and `R4` and specifying their tagged values `ID` and `RE`.
4) Applying `Condition` stereotype on `C1` and `C2` and specifying the appropriate operations `Operation`.
5) Applying `Target` stereotype and its substereotypes on the relevant targets elements and specifying the relevant tagged values of `Subject`, `Resource`, and `Action`.
6) Associate the elements together.

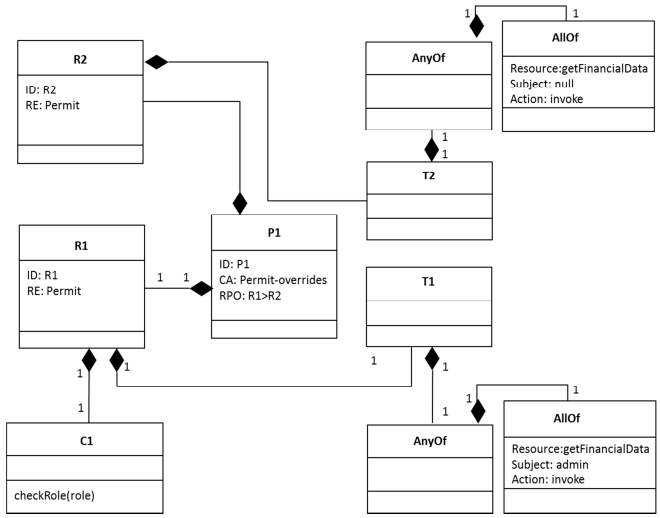
Figure 5 depicts the model after applying the systematic transformation described above. Due to space restrictions, we split the model on different Figures 5a 5b, and 5c.

```
<? xml version ="1.0" encoding =" UTF -8"? >
<PolicySet xmlns="schema :os" PolicyCombiningAlgId="policy-combining-algorithm:permit-overrides" PolicySetId ="PS1">
  <Policy xmlns="urn:oasis:names:tc:xacml:3.0:core:schema:wd-17" PolicyId="P1"
 RuleCombiningAlgId="urn:oasis:names:tc:xacml:1.0:rule-combining-algorithm:permit-overrides" Version="1.0">
    <Description>finanacial data policy</Description>
    <Target></Target>
    <Rule Effect="Permit" RuleId="R1">
      <Target>
        <AnyOf>
          <AllOf>
            <Match MatchId="urn:oasis:names:tc:xacml:1.0:function:string-regexp-match">
              <AttributeValue DataType="http://www.w3.org/2001/XMLSchema#string">
              http://localhost:8280/fsservices/getFinancialData/</AttributeValue>
              <AttributeDesignator AttributeId="urn:oasis:names:tc:xacml:1.0:resource:resource-id"
              Category="urn:oasis:names:tc:xacml:3.0:attribute-category:resource"
              DataType="http://www.w3.org/2001/XMLSchema#string" MustBePresent="true"></AttributeDesignator>
            </Match>
            <Match MatchId="urn:oasis:names:tc:xacml:1.0:function:string-equal">
              <AttributeValue DataType="http://www.w3.org/2001/XMLSchema#string">invoke</AttributeValue>
              <AttributeDesignator AttributeId="urn:oasis:names:tc:xacml:1.0:action:action-id"
              Category="urn:oasis:names:tc:xacml:3.0:attribute-category:action"
              DataType="http://www.w3.org/2001/XMLSchema#string"
              MustBePresent="true"></AttributeDesignator>
            </Match>
          </AllOf>
        </AnyOf>
      </Target>
      <Condition>
        <Apply FunctionId="urn:oasis:names:tc:xacml:1.0:function:string-subset">
          <Apply FunctionId="urn:oasis:names:tc:xacml:1.0:function:string-bag">
            <AttributeValue DataType="http://www.w3.org/2001/XMLSchema#string">admin</AttributeValue>
          </Apply>
          <AttributeDesignator AttributeId="group" Category="urn:oasis:names:tc:xacml:3.0:group"
          DataType="http://www.w3.org/2001/XMLSchema#string" MustBePresent="true"></AttributeDesignator>
        </Apply>
      </Condition>
    </Rule>
    <Rule Effect="Permit" RuleId="R2">
      <Target>
        <AnyOf>
          <AllOf>
            <Match MatchId="urn:oasis:names:tc:xacml:1.0:function:string-regexp-match">
              <AttributeValue DataType="http://www.w3.org/2001/XMLSchema#string">
              http://localhost:8280/fsservices/getFinancialData/</AttributeValue>
              <AttributeDesignator AttributeId="urn:oasis:names:tc:xacml:1.0:resource:resource-id"
              Category="urn:oasis:names:tc:xacml:3.0:attribute-category:resource"
              DataType="http://www.w3.org/2001/XMLSchema#string" MustBePresent="true"></AttributeDesignator>
            </Match>
            <Match MatchId="urn:oasis:names:tc:xacml:1.0:function:string-equal">
              <AttributeValue DataType="http://www.w3.org/2001/XMLSchema#string">invoke</AttributeValue>
              <AttributeDesignator AttributeId="urn:oasis:names:tc:xacml:1.0:action:action-id"
              Category="urn:oasis:names:tc:xacml:3.0:attribute-category:action"
              DataType="http://www.w3.org/2001/XMLSchema#string"
              MustBePresent="true"></AttributeDesignator>
            </Match>
          </AllOf>
        </AnyOf>
      </Target>
  </Policy>
  <Policy xmlns="urn:oasis:names:tc:xacml:3.0:core:schema:wd-17" PolicyId="P2"
  RuleCombiningAlgId="urn:oasis:names:tc:xacml:1.0:rule-combining-algorithm:deny-overrides" Version="1.0">
    <Description>reservation policy</Description>
    <Target></Target>
    <Rule Effect="Permit" RuleId="R3">
      <Target>
        <AnyOf>
          <AllOf>
            <Match MatchId="urn:oasis:names:tc:xacml:1.0:function:string-regexp-match">
              <AttributeValue DataType="http://www.w3.org/2001/XMLSchema#string">
              http://localhost:8280/fsservices/makeReservation/</AttributeValue>
              <AttributeDesignator AttributeId="urn:oasis:names:tc:xacml:1.0:resource:resource-id"
              Category="urn:oasis:names:tc:xacml:3.0:attribute-category:resource"
              DataType="http://www.w3.org/2001/XMLSchema#string" MustBePresent="true"></AttributeDesignator>
            </Match>
            <Match MatchId="urn:oasis:names:tc:xacml:1.0:function:string-equal">
              <AttributeValue DataType="http://www.w3.org/2001/XMLSchema#string">invoke</AttributeValue>
              <AttributeDesignator AttributeId="urn:oasis:names:tc:xacml:1.0:action:action-id"
              Category="urn:oasis:names:tc:xacml:3.0:attribute-category:action"
              DataType="http://www.w3.org/2001/XMLSchema#string"
              MustBePresent="true"></AttributeDesignator>
            </Match>
          </AllOf>
        </AnyOf>
      </Target>
    <Rule Effect="Deny" RuleId="R4">
      <Target>
        <AnyOf>
          <AllOf>
            <Match MatchId="urn:oasis:names:tc:xacml:1.0:function:string-regexp-match">
              <AttributeValue DataType="http://www.w3.org/2001/XMLSchema#string">
              http://localhost:8280/fsservices/makeReservation/</AttributeValue>
              <AttributeDesignator AttributeId="urn:oasis:names:tc:xacml:1.0:resource:resource-id"
              Category="urn:oasis:names:tc:xacml:3.0:attribute-category:resource"
              DataType="http://www.w3.org/2001/XMLSchema#string" MustBePresent="true"></AttributeDesignator>
            </Match>
            <Match MatchId="urn:oasis:names:tc:xacml:1.0:function:string-equal">
              <AttributeValue DataType="http://www.w3.org/2001/XMLSchema#string">invoke</AttributeValue>
              <AttributeDesignator AttributeId="urn:oasis:names:tc:xacml:1.0:action:action-id"
              Category="urn:oasis:names:tc:xacml:3.0:attribute-category:action"
              DataType="http://www.w3.org/2001/XMLSchema#string"
              MustBePresent="true"></AttributeDesignator>
            </Match>
          </AllOf>
        </AnyOf>
      </Target>
      <Condition>
        <Apply FunctionId="urn:oasis:names:tc:xacml:1.0:function:and">
          <Apply FunctionId="urn:oasis:names:tc:xacml:1.0:function:time-greater-than-or-equal">
            <AttributeDesignator AttributeId="urn:oasis:names:tc:xacml:1.0:environment:current-time"
            Category="urn:oasis:names:tc:xacml:3.0:attribute-category:environment"
            DataType="http://www.w3.org/2001/XMLSchema#time"
            MustBePresent="true"/>
            <AttributeValue DataType="http://www.w3.org/2001/XMLSchema#time">09:00:00</AttributeValue>
          </Apply>
          <Apply FunctionId="urn:oasis:names:tc:xacml:1.0:function:time-less-than-or-equal">
            <AttributeDesignator AttributeId="urn:oasis:names:tc:xacml:1.0:environment:current-time"
            Category="urn:oasis:names:tc:xacml:3.0:attribute-category:environment"
            DataType="http://www.w3.org/2001/XMLSchema#time"
            MustBePresent="true"/>
            <AttributeValue DataType="http://www.w3.org/2001/XMLSchema#time">16:00:00</AttributeValue>
          </Apply>
        </Apply>
      </Condition>
    </Rule>
  </Policy>
</PolicySet>
```

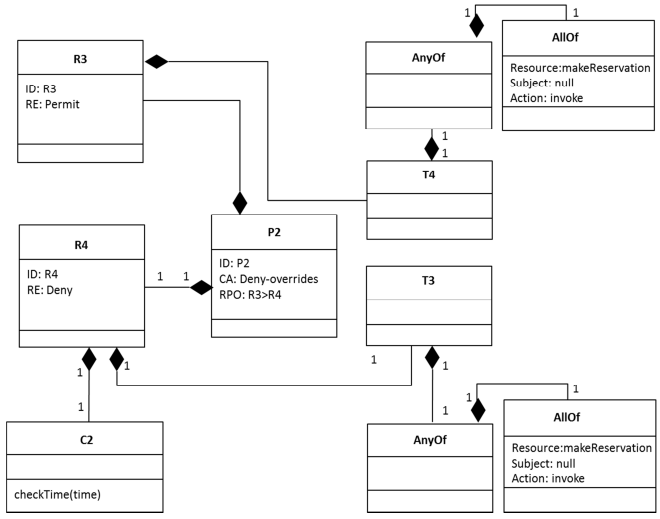
Fig. 4: XACML Security Policy Set for FS



(a) Policy Set PS



(b) Policy P1 and its Associated Elements



(c) Policy P2 and its Associated Elements

Fig. 5: Design-Model of Security Policies for FS

B. Design-Level Security Policies Analysis

After the specification of security policies and automatic generation of their corresponding sets, the proposed analyzer module takes care of the detection of existing problems and vulnerabilities in the policy set based on the policies semantics. Figure 6 presents a synopsis of the generate analysis report. The highlighted parts demonstrates the capability of the proposed algorithms to detect access flaws, conflicts and redundancies between policies and rules in the policy set.

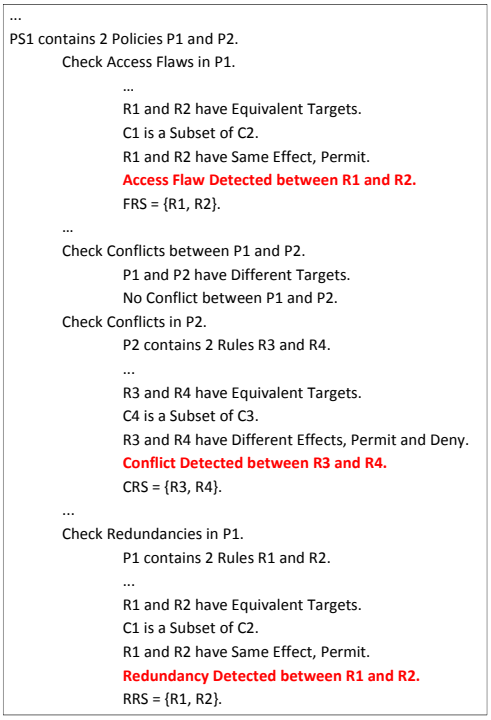


Fig. 6: Synopsis of the Generated Analysis Report

IV. Related Work

In what follows, we present existing works for model-driven security specification and security policies analysis.

In [2], the authors proposed a model-driven approach to define and integrate security aspects in Web services composition. They presented a UML profile that extends the Business Process Execution Language to offer high-level specification of security aspects. Their work relies on specific aspect security language for BPEL, yet our approach relies on the standard XACML language. Jin [3] has proposed model-driven architecture to build role based access control (RBAC) model. To address the complexity of XACML XML-based documents, they proposed a UML profile that provides UML notations to ease the specification of XACML RBAC applications. Also, Busch et al. [4] argued that XML syntax of XACML makes the process of policies specification difcult and error-prone and thus they proposed a UML-based notation to offers graphical modelling of security properties. However, the notations presented in both approaches did not cover all the elements of XACML policies like obligations, and most importantly, they rely on XACML 2.0, which is not the latest version of XACML. Per contra, we presented in this paper a UML profile that covers all the elements of the latest version of XACML, offering the ability to design any policy that can be expressed in this language.

The approach proposed in [6] is dealing with conflicts, yet did address other problems like those we presented throughout this paper. Kolovski et al. [7] proposed a formalization of XACML using description logics (DL) and verification using the existing DL verifiers. Even though their analysis is able to detect redundancies between rules, yet they don't provide means for detecting access flaws and even they do not support conditions and some combining algorithms. Rao et al. [8] introduced an algebra for fine-grained integration supporting specification of integration constraints. However, they missed many elements of XACML like rule conditions and obligations. Opposed to our work, these approaches cannot support important elements in XACML, discarded some critical problems and vulnerabilities, and more essentially, none of them has proposed analysis at the design level.

V. Conclusion and Future Directions

This paper presented a UML profile for the latest version of XACML to provide high-level specification of security policies, and design-level analysis to detect problems and vulnerabilities like conflicts, redundancies, and access flaws, in the defined policies semantics, a priori to their application at runtime. As for future work, we plan to address different type of flaws that can arise between policies especially those that can threaten more complex systems like Web services composition.

References

[1] Erik Rissanen. extensible access control markup language (xacml) version 3.0 (committe specification 01). Technical report, OASIS, http://docs.oasisopen.org/xacml/3.0/xacml-3.0-core-spec-cd-03-en.pdf, 2010.

[2] Hanine Tout, Azzam Mourad, Hamdi Yahyaoui, Chamseddine Talhi, and Hadi Otrok. Towards a bpel model-driven approach for web services security. In *Privacy, Security and Trust (PST), 2012 Tenth Annual International Conference on*, pages 120–127. IEEE, 2012.

[3] Xin Jin. *Applying model driven architecture approach to model role based access control system*. PhD thesis, University of Ottawa, 2006.

[4] Marianne Busch, Nora Koch, Massimiliano Masi, Rosario Pugliese, and Francesco Tiezzi. Towards model-driven development of access control policies for web applications. In *Proceedings of the Workshop on Model-Driven Security*, page 4. ACM, 2012.

[5] OASIS. Omg unified modeling language^{TM} (omg uml) version 2.5. Technical report, OASIS, http://www.sce.carleton.ca/courses/sysc-5708/f14/UML2_5-ptc-13-09-05.pdf, 2013.

[6] Florian Huonder, Josef M Joller, and ZH Rüschlikon. Conflict detection and resolution of xacml policies. In *RAPPERSWIL, SWITZERLAND*. Citeseer, 2010.

[7] Vladimir Kolovski, James Hendler, and Bijan Parsia. Analyzing web access control policies. In *Proceedings of the 16th international conference on World Wide Web*, pages 677–686. ACM, 2007.

[8] Prathima Rao, Dan Lin, Elisa Bertino, Ninghui Li, and Jorge Lobo. An algebra for fine-grained integration of xacml policies. In *Proceedings of the 14th ACM symposium on Access control models and technologies*, pages 63–72. ACM, 2009.

[9] Said Marouf, Mohamed Shehab, Anna Squicciarini, and Smitha Sundareswaran. Adaptive reordering and clustering-based framework for efficient xacml policy evaluation. *Services Computing, IEEE Transactions on*, 4(4):300–313, 2011.

[10] Canh Ngo, Marc X Makkes, Yuri Demchenko, and Cees de Laat. Multi-data-types interval decision diagrams for xacml evaluation engine. In *Privacy, Security and Trust (PST), 2013 Eleventh Annual International Conference on*, pages 257–266. IEEE, 2013.