Semantics-Enabled Web Policies for Privacy Protection: Current Status and Future Trend

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Part I

Research Goals

Short Term Research Goals

Semantics-Enabled privacy protection policies

- A formal semantic policy model of P3P and EPAL
- Data sharing and protection on the Web
- Data integration and protection in the cloud

Current Status[16]

- Semantics-enabled of privacy protection policies
- Policies alignment between semantics-enabled P3P and EPAL
- A semantic privacy-preserving model for data sharing and integration

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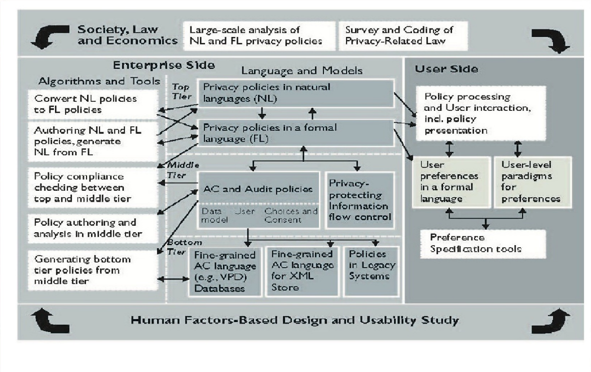
The Framework for an Online Privacy Policy Management



–Annie I. Ant'on et al., CACM, 50(7), July 2007.

Long Term Research Goals

SemPIF Framework: PIF + Meta-PIF

- Policy Interchange Format (PIF)
- Meta-PIF for policy management services

Legalized Computer-Enabled Policy

- Semantics-enabled privacy protection policies and systems
- Enforcing privacy policies across multiple domains
- Legalized privacy protection policies

Long Term Research Goals

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Part II

Semantics-Enabled Web Policies

Policy Representation

Natural Language

- Pros: human readable and understandable
- Cons: machine unfriendly, no formal semantics

Pure FOL

- Pros: formal and clear syntax and semantics
- Cons: machine unfriendly, possibly undecidable computation; policy writer (or reader) needs to be a logician

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Policy Representation (conti.)

Rights Expression Languages

- Pros: machine processing of its XML-based documents
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Ontology+Rule with XML Presentation Syntax

- Pros: automatic machine processing and understanding
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What Do You Mean Computer-Based Policies?

Definition (Computer-Based Policies)

- Declared as knowledge bases, i.e., ontologies and rules
- Reducing program coding to a minimum level
- Framework supports policy interoperability
- Low deployment and maintenance cost
- Machine understandable on context of policies

Policy Specification, Enforcement, and Integration, WG I2, REWERSE FP6

What Do You Mean Meta-Policies?

Definition (Meta-Policy)

- A policy about policies
- Enforcing policy management services for adding/changing/coordination
- Allowing to set up policy priority to enforce, negotiate, and resolve conflicts of multi-policies

Hosmer, H. H., Metapolicies I, ACM SIGSAC Review, 1992

XML-Based Policy Lacks Semantics

XML-based Policy Languages

- XrML [18] ⇐ digital rights expression language
- ODRL [17] ⇐ digital rights expression language
- P3P [6] ⇐ privacy rights expression language
- EP3P (EPAL) [2] ⇐ privacy rights expression language
- XACML [2] ⇐ general policy language and framework

Pure FOL-Based Policies Are Not Web-Enabled

Formal semantics of policies in DL or LP

- Semantic ODRL [27] $\Leftarrow$ FOL semantics
- Semantic XrML [11] $\Leftarrow$ FOL semantics
- Semantic P3P [34] $\Leftarrow$ relational semantics
- FAF [19] $\Leftarrow$ LP semantics
- Semantic E-P3P (or EPAL) [2] $\Leftarrow$ FAF semantics
- Rein, KAoS [32] $\Leftarrow$ DL-based FOL semantics
- Protune [4] $\Leftarrow$ LP semantics
- AIR [1] $\Leftarrow$ RDF semantics

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Semantics-Enabled Web Policies

Policies in semantic web languages

- Ontology Languages: RDF(S), OWL-DL, OWL2
- Rules Languages: N3, RuleML, RIF
- Ontology+Rule Language: SWRL, OWL2-RL

Semantics-Enabled Web Policies (conti.)

Why use ontology+rule?

- Exploiting two semantic web core technologies
- Automatic machine processing of policies
- Major knowledge representations on the Web
- Allowing policy interchange, interoperation, and integration

Why not use ontologies or rules alone?

- Policies might be in DL or in LP semantics
- Power enhancement from ontologies and rules
- Options to use ontologies, rules alone or both

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Semantics-Enabled Web Policies (conti.)

Which ontology+rule combination for Policies?

- Issues to consider:
  1. Decidability of computation
  2. Expressive power of ontology+rule
  3. Semantics differences between DL and LP
  4. Uni-(or bi-)directional of knowledge flow
  5. Homogeneous of ontology+rule
  6. Heterogeneous of ontology+rule

Semantics-Enabled Web Policy (conti.)

Homogeneous of Ontology+Rule [30]

- CARIN [21]
- Description Logic Program (DLP) [9]
- Semantic Web Rule Language (SWRL) [13]
- OWL2-RL

Part III

Privacy Protection Policies

Privacy Protection on the Web

Privacy Protection on the Web 1.0

- Policy representation through natural language
- Profile and digital traces
- Policies and mechanisms are embedded together
- Whether policies comply with the laws? Unknown!

Privacy Protection on the Web 2.0

- Information disclosure's opt-in/opt-out
- Digital traces protection is an issue
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- Information disclosure's opt-in/opt-out
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Privacy Protection on the Web 3.0

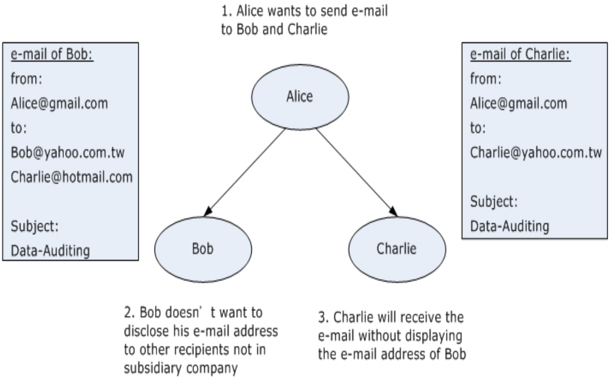
- Decoupling policies and mechanisms
- Semantics-enabled of profile and digital traces format
- Machine automatic enforcement of policies
- Machine auditing and verifying the compliance of policies

Natural Language for Mail Sending Policies

Example (Policies as Natural Language)

Under company *SD* internal regulation, anyone sends an email through a mailing list with multiple recipients, where email recipients $\in SD$ cannot be disclosed his/her email address to those people not $\in SD$ domain under any purposes. Therefore, the email recipient $Charlie \in CP$ cannot explicitly see the email address of the recipient $Bob \in SD$ in his receiving email address header.

Non-disclosure of a recipient's email address



Ontology Module

Example (Axiom in an Ontology Module)

- $COMPANY \sqsubseteq PRIVATE$
- $PRIVATE \sqsubseteq ORGANIZATION$
- $OWNER \sqsubseteq PERSON$
- $COMPANY \xleftarrow{domain} HAS\_COOPERATIVE \xrightarrow{range} COMPANY$
- $COMPANY \xleftarrow{domain} HAS\_SUBSIDIARY \xrightarrow{range} COMPANY$
- $HAS\_COOPERATIVE \equiv HAS\_COOPERATIVE^{-}$
- $PERSON \xleftarrow{domain} IS\_STAFF\_OF \xrightarrow{range} ORGANIZATION$
- $MAIL\_TRACE \xleftarrow{domain} HAS\_MAIL\_TRACE \xrightarrow{range} EMAIL$
- $EMAIL \sqsubseteq \exists\ HAS\_MAIL\_TRACE\_ONLINE^{-}.O\_EMAIL\_SENDER$
- $EMAIL \sqsubseteq \forall\ HAS\_MAIL\_TRACE\_ONLINE.O\_EMAIL\_RECEIVER$
- $DATA\_AUDIT\_ANNOUN. \sqsubseteq AUDIT\_ANNOUN.$

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- $DATA\_AUDIT\_ANNOUN. \sqsubseteq AUDIT\_ANNOUN.$

Ontology Module

Example (Facts in an Ontology Module)

- *ORGANIZATION(G)*
- *HAS_SUBSIDIARY(G, J-Corp.)*
- *HAS_COOPERATIVE(G, Q-Corp.)*
- *IS_STAFF_OF(Alice, J-Corp.)*
- *IS_STAFF_OF(Bob, J-Corp.)*
- *IS_STAFF_OF(Charlie, Q-Corp.)*
- *HAS_EMAIL_ADDRESS (Charlie,Charlie@hotmail.com)*
- *O_EMAIL_RECEIVER(Bob@yahoo.com.tw)*
- *HAS_EMAIL_ADDRESS (Alice,Alice@gmail.com)*
- *HAS_EMAIL_ADDRESS (Bob,Bob@yahoo.com.tw)*
- *O_EMAIL_SENDER(Alice@gmail.com),*
- *O_EMAIL_RECEIVER (Charlie@hotmail.com)*
- *HAS_MAIL_TRACE_ONLINE (Alice@gmail.com,Bob@yahoo.com.tw)*
- *HAS_MAIL_TRACE_ONLINE (Alice@gmail.com,Charlie@hotmail.com)*

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- *HAS_EMAIL_ADDRESS (Charlie,Charlie@hotmail.com)*
- *O_EMAIL_RECEIVER(Bob@yahoo.com.tw)*
- *HAS_EMAIL_ADDRESS (Alice,Alice@gmail.com)*
- *HAS_EMAIL_ADDRESS (Bob,Bob@yahoo.com.tw)*
- *O_EMAIL_SENDER(Alice@gmail.com),*
- *O_EMAIL_RECEIVER (Charlie@hotmail.com)*
- *HAS_MAIL_TRACE_ONLINE (Alice@gmail.com,Bob@yahoo.com.tw)*
- *HAS_MAIL_TRACE_ONLINE (Alice@gmail.com,Charlie@hotmail.com)*

Rule Module

Example (Rules in a Rule Module)

- **cando**(*?c,?b-email, display)*
  $\Longleftarrow$ *opt-in(?b,?b-email,?p)), data-user(?c), data-owner(?b), HAS_EMAIL_ADDRESS(?b,?b-email).* $\leftarrow$ *(a1)*
- **cando**(*?c,?b-email, nill)*
  $\Longleftarrow$ *opt-out(?b,?b-email,?p)), data-user(?c), data-owner(?b), HAS_EMAIL_ADDRESS(?b, ?b-email).* $\leftarrow$ *(a2)*
- *opt-in(?b,?b-email,?p)*
  $\Longleftarrow$ *data-owner(?b), data-user(?c), purpose(?p), data-type(?b-email), IS_STAFF_OF(?b,?c1), IS_STAFF_OF(?c, ?c2), HAS_SUBSIDIARY(?c1,?c2), HAS_MAIL_TRACE_ONLINE(?a-email,?c-email), O_EMAIL_SENDER(?a-email), O_EMAIL_RECEIVER(?c-email).* $\leftarrow$ *(a3)*
- *opt-out(?b,?b-email,?p)*
  $\Longleftarrow$ *data-owner(?b), data-user(?c), purpose(?p), data-type(?b-email), IS_STAFF_OF(?b,?c1), IS_STAFF_OF(?c, ?c2), HAS_COOPERATIVE(?c1,?c2), HAS_MAIL_TRACE_ONLINE(?a-email,?c-email), O_EMAIL_SENDER(?a-email), O_EMAIL_RECEIVER(?c-email).* $\leftarrow$ *(a4)*

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- **cando***(?c,?b-email, display)*
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- *opt-out(?b,?b-email,?p)*
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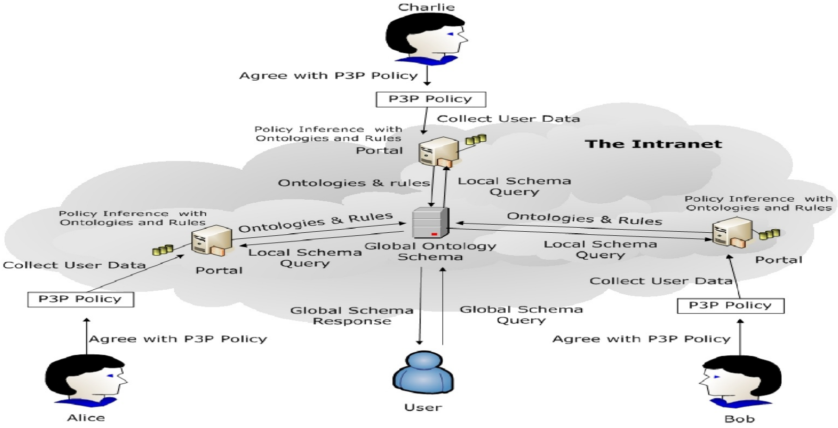
Rule Module

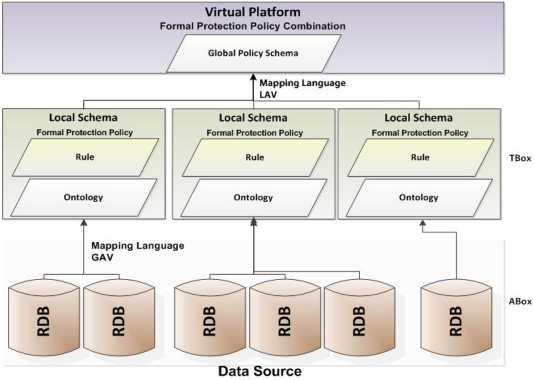
Example (Facts in a Rule Module)

- *data-user(Bob), data-owner(Bob),*
- *data-user(Charlie), data-owner(Charlie),*
- *purpose(data-auditing),*
- *data-type(Bob@yahoo.com.tw),*
- *data-type(Charlie@hotmail.com),*
- *opt-in(c,Charlie@yahoo.com, data-auditing),*
- *cando(Bob,Charlie@yahoo.com,display),*
- *cando(Charlie,Bob@yahoo.com.tw,nill),*
- *opt-out(b,Bob@yahoo.com.tw, data-auditing)*

Semantics-Enabled of P3P and EPAL



A Semantic Privacy Protection Model



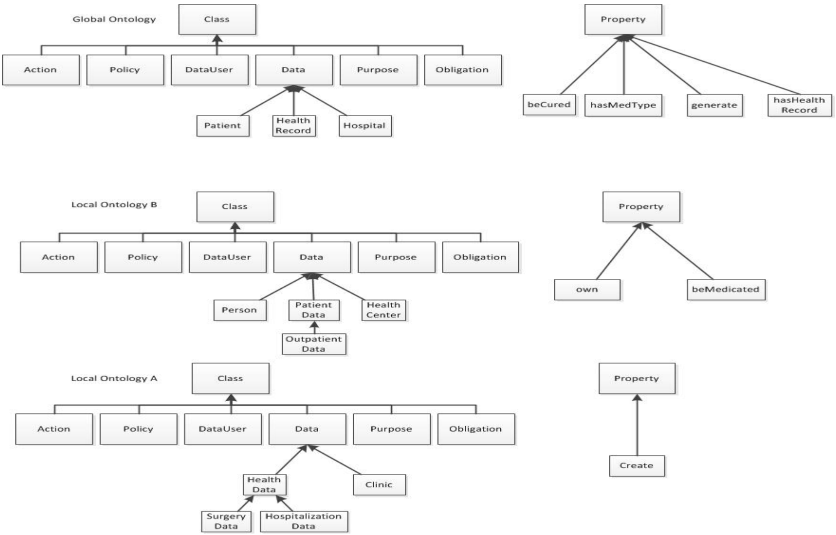
EHR Usage Policies

Example (Policies as Natural Language)

Under the data protection law, two hospitals, `A` and `B`, have allowed to share their patients' Electronic Health Records (EHRs) after patients give their consents for various medication purposes.

A patient was hospitalized in hospital `A` for a surgery. After that, this patient went to hospital `B` for an outpatient medication. A physician in the hospital `B` was authorized to query this patient's shareable EHR at the $\mathcal{VP}$ collected from hospital `A` and hospital `B`'s RDB data sources.

A Partial Ontology for EHR Sharing and Protection



Vocabularies for the Hospital LS_A and LS_B

Partial ontology of LS_A vocabularies

Class:
SurgeryData $\sqsubseteq$ Clinic, HospitalizationData $\sqsubseteq$ HealthData

Property:
T $\sqsubseteq \forall$ create.Hospital, T $\sqsubseteq \forall$ create$^-$.HealthData

Partial ontology of LS_B vocabularies

Class:
Person, HealthCenter, OutPatientData $\sqsubseteq$ PatientData

Property:
T $\sqsubseteq \forall$ own.Person, T $\sqsubseteq \forall$ own$^-$.PatientData.

T $\sqsubseteq \forall$ beMedicated.Person, T $\sqsubseteq \forall$ beMedicated$^-$.HealthCenter.

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Views Use at the $\mathcal{VP}$

Views Created from LS_A

$\texttt{def}(\texttt{V1}_{\texttt{Clinic}}) = \texttt{Hospital}$
$\texttt{def}(\texttt{V2}_{\texttt{HealthData}}) = \texttt{HealthRecord}$
$\texttt{def}(\texttt{V3}_{\texttt{SuregeryData}}) = \texttt{HealthRecord} \wedge \forall \texttt{hasMedType.Surgery}$
$\texttt{def}(\texttt{V4}_{\texttt{HospitalizationData}}) = \texttt{HealthRecord} \wedge \forall\ \texttt{hasMedType.Hospitalization}$

$\texttt{def}(\texttt{V5}_{\texttt{create}}) = \texttt{generate}$

Views Created from LS_B

$\texttt{def}(\texttt{V6}_{\texttt{Person}}) = \texttt{Patient}$
$\texttt{def}(\texttt{V7}_{\texttt{HealthCenter}}) = \texttt{Hospital}$
$\texttt{def}(\texttt{V8}_{\texttt{PatientData}}) = \texttt{HealthRecord}$
$\texttt{def}(\texttt{V9}_{\texttt{OutPatientData}}) = \texttt{HealthRecord} \wedge \forall\ \texttt{hasMedType.OutPatient}$
$\texttt{def}(\texttt{V10}_{\texttt{beMedicated}}) = \texttt{beCured}$

$\texttt{def}(\texttt{V11}_{\texttt{own}}) = \texttt{hasHealthRecrod}$

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A Physician Queries at the $\mathcal{VP}$

Original Query

$\texttt{Patient}(?x) \wedge \texttt{beCured}(?x, ?y) \wedge \texttt{hasHealthRecrod}(?x, ?r) \wedge \texttt{HealthRecord}(?r) \wedge \texttt{hasMedType}(?r, \texttt{Surgery}) \wedge \texttt{generate}(?y, ?r) \longrightarrow \texttt{sqwrl} : \texttt{select}(?x, ?r)$

Rewriting Queries One

$\texttt{V6}_{\texttt{Person}} \wedge \texttt{V10}_{\texttt{beMedicated}} \wedge \texttt{V11}_{\texttt{own}} \wedge \texttt{V9}_{\texttt{OutPatientData}} \wedge \texttt{V5}_{\texttt{create}} \longrightarrow \texttt{sqwrl} : \texttt{select}(?x, ?r)$

$\texttt{B} : \texttt{Person}(?p) \wedge \texttt{B} : \texttt{beMedicated}(?p, ?c) \wedge \texttt{B} : \texttt{own}(?p, ?d) \wedge \texttt{B} : \texttt{OutPatientData}(?od) \wedge \texttt{A} : \texttt{create}(?h, ?hd) \longrightarrow \texttt{sqwrl} : \texttt{select}(?p, ?od)$

Rewriting Queries Two

$\texttt{V6}_{\texttt{Person}} \wedge \texttt{V10}_{\texttt{beMedicated}} \wedge \texttt{V11}_{\texttt{own}} \wedge \texttt{V3}_{\texttt{SuregeryData}} \wedge \texttt{V5}_{\texttt{create}} \longrightarrow \texttt{sqwrl} : \texttt{select}(?x, ?r)$

$\texttt{B} : \texttt{Person}(?p) \wedge \texttt{B} : \texttt{beMedicated}(?p, ?c) \wedge \texttt{B} : \texttt{own}(?p, ?d) \wedge \texttt{A} : \texttt{SuregeryData}(?sd) \wedge \texttt{A} : \texttt{create}(?h, ?hd) \longrightarrow \texttt{sqwrl} : \texttt{select}(?p, ?sd)$

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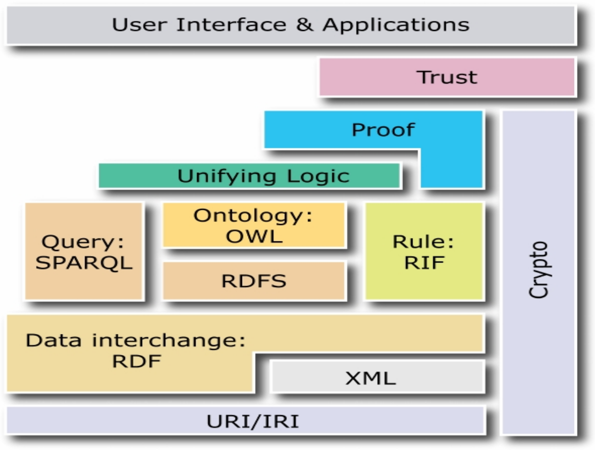
Part IV

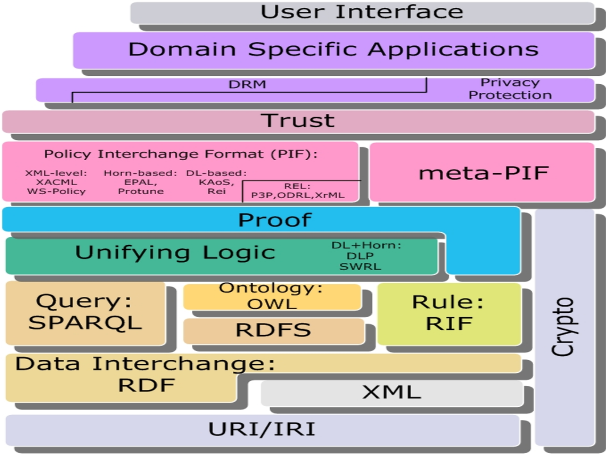
SemPIF (Cooperation with IIT NRC, Canada)

Well-Known Semantic Web Layer Cake (2007 Version)



–http://www.w3.org/2007/03/layerCake.svg

SemPIF Extends Semantic Web Architecture



SemPIF's Related Work

Where Are Current Available Policy Frameworks?

- W3C PLING
- OMG SBVR
- MIT DIG Rein
- FP6 REWERSE Protune
- W3C Policy Working Group Privacy Rulesets

What Are the Features of SemPIF

- Extends from the Semantic Web architecture
- Explicitly decoupling meta-PIF from PIF
- A combination of ontology+rule

SemPIF's Related Work

Where Are Current Available Policy Frameworks?

- W3C PLING
- OMG SBVR
- MIT DIG Rein
- FP6 REWERSE Protune
- W3C Policy Working Group Privacy Rulesets

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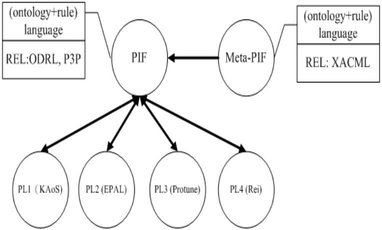
Research Issues in SemPIF

Could be more than the following!

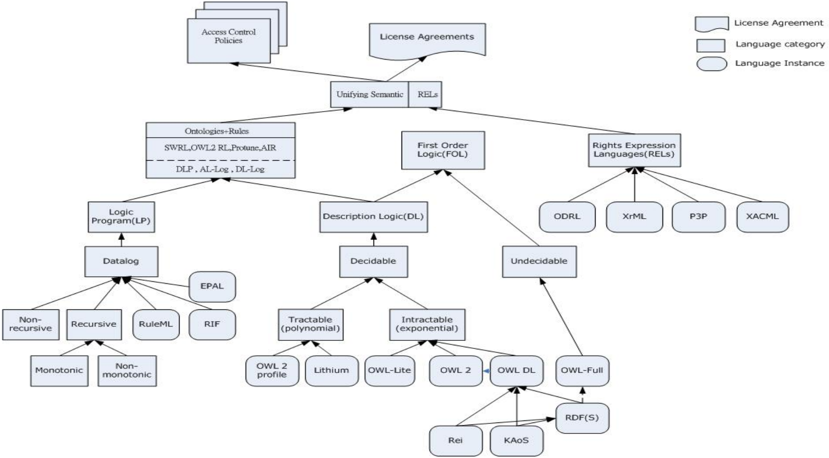
- Policy representation and enforcement
- Policy interoperability and management services
- Policy negotiation and conflict resolution
- Trust establishment on the Web

Policy Management Services in Meta-Policies

- Policies are formulated as knowledge bases, i.e., ontology+rule.
- Meta-policies are also formulated as ontology+rule, which provides a set of rules to enforce policy management services, such as naming/adding/deleting/updating/integration, and conflict resolution, etc.



Taxonomy of Semantic Rights Expression Language for Policies



A Scenario of Digital Library Subscription

Server side's policy description as natural language

- The NCCU university library has subscribed to IEEE, ACM, and Springer digital library services, which provide a set of eJournal article access rights for authorized students and staff.
- There are two types of policy for an IEEE Web server: one is for DRM and the other one is for privacy statement declaration.

Client side's policy description as natural language

- A student, as a Web client, has privacy protection policies to address how and what of his personal data can (or cannot) be collected, retained, or disclosed in a Web server.

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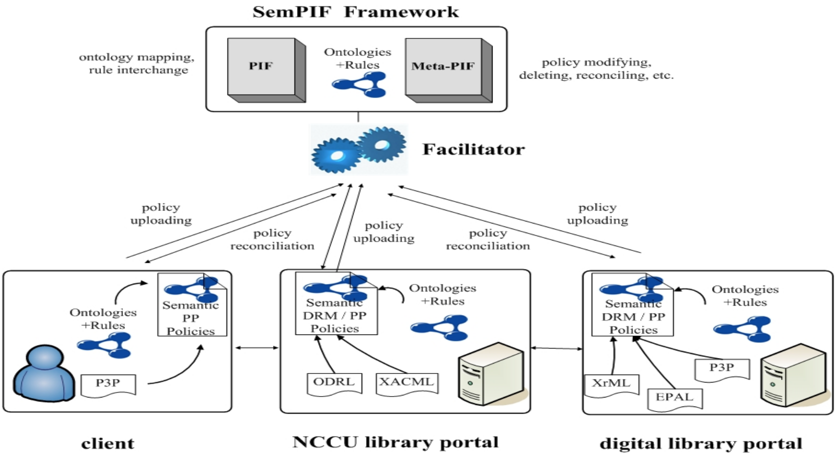
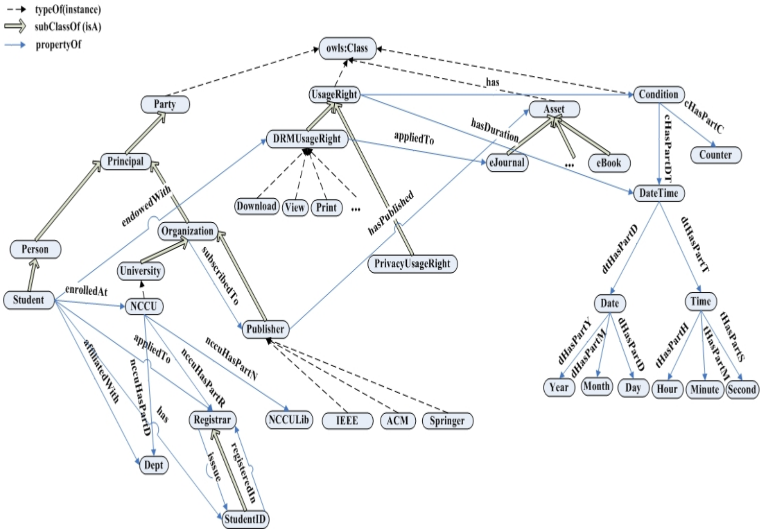
Agents in the Facilitator for Policy Integration Services



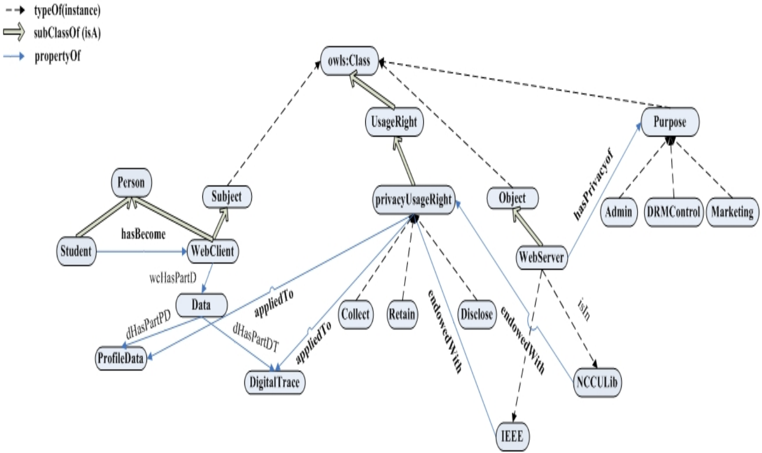
A PIF-based Ontology for a DRM Policy



A PIF-based Rule for a Server's DRM Policy

$$
\begin{aligned}
&\texttt{?st\#Student}\wedge\texttt{?id\#StudentID}\wedge\texttt{?st[own}\rightarrow\texttt{?id]}\\
&\wedge\texttt{?uni[nccuHasPartR}\rightarrow\texttt{?rg]}\wedge\texttt{?st[enrolledAt}\rightarrow\texttt{?uni]}\\
&\wedge\texttt{?rg[issue}\rightarrow\texttt{?id]}\wedge\texttt{?uni[nccuhasPartN}\rightarrow\texttt{?lib]}\\
&\wedge\texttt{?lib[subscribedTo}\rightarrow\texttt{IEEE]}\wedge\texttt{IEEE[hasPublished}\rightarrow\texttt{?ejr]}\\
&\wedge\texttt{IEEE[endowedWith}\rightarrow\texttt{?rgt]}\wedge\texttt{?rgt[appliedTo}\rightarrow\texttt{?ejr]}\\
&\wedge\texttt{IEEE[delegate}\rightarrow\texttt{?st]}\\
\Longrightarrow&\texttt{?st[endowedWith}\rightarrow\texttt{?d]}\wedge\texttt{?st[endowedWith}\rightarrow\texttt{?v]}\\
&\wedge\texttt{?st[endowedWith}\rightarrow\texttt{?p]}\wedge\texttt{?d\#Download}\wedge\texttt{?d[appliedTo}\rightarrow\texttt{?ejr]}\\
&\wedge\texttt{?v\#View}\wedge\texttt{?v[appliedTo}\rightarrow\texttt{?ejr]}\wedge\texttt{?p\#Print}\wedge\texttt{?p[appliedTo}\rightarrow\texttt{?ejr]}.
\end{aligned}
$$

A PIF-based Ontology for a Privacy Protection Policy



A PIF-based Rule for a Client's Privacy Protection Policy

$$
\begin{aligned}
&\texttt{?per[endowedWith} \rightarrow \texttt{?drmr]} \wedge \texttt{?drmr[appliedTo} \rightarrow \texttt{?ejr]}\\
&\wedge \texttt{IEEE[hasPublished} \rightarrow \texttt{?ejr]} \wedge \texttt{IEEE[hasPrivacyOf} \rightarrow \texttt{DRMControl]}\\
&\wedge \texttt{?per[dHasPartPD} \rightarrow \texttt{?prf]} \wedge \texttt{?per[dHasPartDT} \rightarrow \texttt{?dif]}\\
&\wedge \texttt{?per[endowedWith} \rightarrow \texttt{?ppr]} \wedge \texttt{?per[delegate} \rightarrow \texttt{IEEE]}\\
&\wedge \texttt{Retain[hasDuration} \rightarrow = \mathsf{2Month}]\\
&\wedge \texttt{?sdtime[dHasPartD} \rightarrow \texttt{?dtime]} \wedge \texttt{?edtime[dHasPartD} \rightarrow \texttt{?dtime]}\\
&\wedge \mathsf{subtract\text{-}dateTimes}(\texttt{?edtime}, \texttt{?sdtime}) \leq \texttt{Retain}\\
\Longrightarrow\ &\texttt{IEEE[endowedWith} \rightarrow \texttt{?ppr]} \wedge \texttt{?ppr[appliedTo} \rightarrow \texttt{?prf]}\\
&\wedge \texttt{?ppr[appliedTo} \rightarrow \texttt{?dif]}.
\end{aligned}
$$

Conclusion and Future Work

Conclusion

1. Semantics-enabled of privacy protection policies are shown as the SWRL with P3P/APPEL rights expression languages.
2. SemPIF, including PIF and meta-PIF, extends the W3C's Semantic Web architecture.
3. Several use case scenarios demonstrate the applicability of our concepts.

Further Study

- The specification of PIF grammar has not yet been completed. In fact, this is a big challenge.
- Another challenge is to verify the meta-PIF concepts for policy management services on the Web.

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