A Quality of Context-Aware Approach to Access Control in Pervasive Environments

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Outline

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Context-Aware Access Control Policies

Example

In case of emergency, any qualified physician located within the hospital is allowed to access Alice's health protected information.

- Access control policies
  - High level directives defining *who* can access *which resource* under *which circumstances*
- Traditional policies based on identities/roles – static
- **Context-aware** access control policies
  - Definition of policies based on context
  - Use of semantic technologies to represent & reason about policies and contexts

Why We Need Quality of Context

- Context information determines behavior & strategies of context-aware security systems
- But is context information *reliable* itself?
  - Unknown – no available sensor information
  - Ambiguous – conflicting information from different sources
  - Imprecise – information with insufficient granularity
  - Erroneous – sensed or aggregated context not coherent with real situation
- Need to explicitly consider the **quality of context** used in security decisions

QoC Awareness & Security – State of the Art

1. QoC representation
   - Declarative models (QoC metadata)
   - Logical models (e.g., FOL, fuzzy logics)
   - Probabilistic models
2. QoC calculation techniques
   - Learning techniques and sensor training (e.g., to calculate precision & correctness)
   - Algorithms to calculate QoC value of aggregated contexts
   - Algorithms to deal with uncertain/ambiguous contexts (conflict resolution)
3. Few context-aware architectures explicitly consider QoC
   - Impact of QoC on context-aware security has not been thoroughly analyzed yet

Outline

Proteus Context & Policy Model

- Proteus policies associate resources to *protection contexts*
- A protection context is a set of attributes & constrained values (*context elements*)
- The current state is a set of attributes & values measured by "sensors" (*context assertions*)
  - A protection context is *active* if context assertions describing the current state match its context elements
- Activation of protection contexts (and associated policies) allows access to a resource

Context & Policy Representation

Example

In case of emergency, any qualified physician located within the hospital is allowed to access Alice's health protected information.

$$\begin{aligned}&\text{PersonalEmergencyContext} \equiv \\ &\text{ProtectionContext} \sqcap \exists\ \text{owner.Alice} \sqcap \exists\ \text{requestor.InHospitalQualifiedPhysician} \sqcap \\ &\exists\ \text{resource.AliceHPI} \sqcap \exists\ \text{environment.PersonalEmergency}\end{aligned}$$

$$< Dr.Green, located, EmergencyRoom >$$
$$< CurrentState, environment, PersonalEmergency >$$

- Context & policy representation based on Description Logic

Quality of Context Model

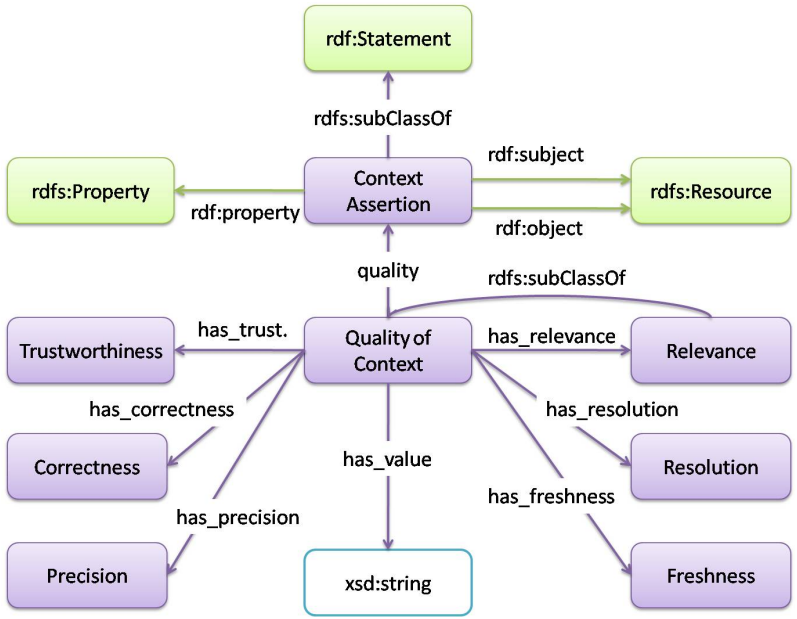
- Proteus associates a *quality attribute* to contexts and policies
- Each quality attribute includes a numerical value and several sub-attributes:
  - freshness, precision, correctness, trustworthiness, relevance, resolution

1. Context elements are associated to constraints on quality attributes (in addition to constraints on context attribute values)
   - Context assertions are associated to a certain value of quality attribute(s) (in addition to values for context attributes)

2. Policies are also associated to QoC constraints (thresholds)

QoC Representation Model

- QoC constraint representation → DL + extension to RDF reification
  - Integrated with Proteus v1.0 – uniform context/policy representation (DL)
  - Compatible with existing DL/RDF reasoners – compliant with RDF model



QoC-based Context Filtering

Example

Any context assertion about the property "located" must be provided with a quality value of 0.8 or above.

$$\text{QoC\_constraint} \equiv \text{CtxAssert} \sqcap \exists \text{ quality.QoC\_over0.8} \sqcap \exists \text{ rdf:property.}\{\text{located}\}$$

- Proteus filters out all context assertions (describing the current state) whose quality level does not satisfy quality constraints
- Context element filtering might depend on context sources and application domain – coarse-grained (from a security perspective)
  - Reducing the number of context assertions improves efficiency
  - Only "reliable enough" context assertions are considered to take security decisions

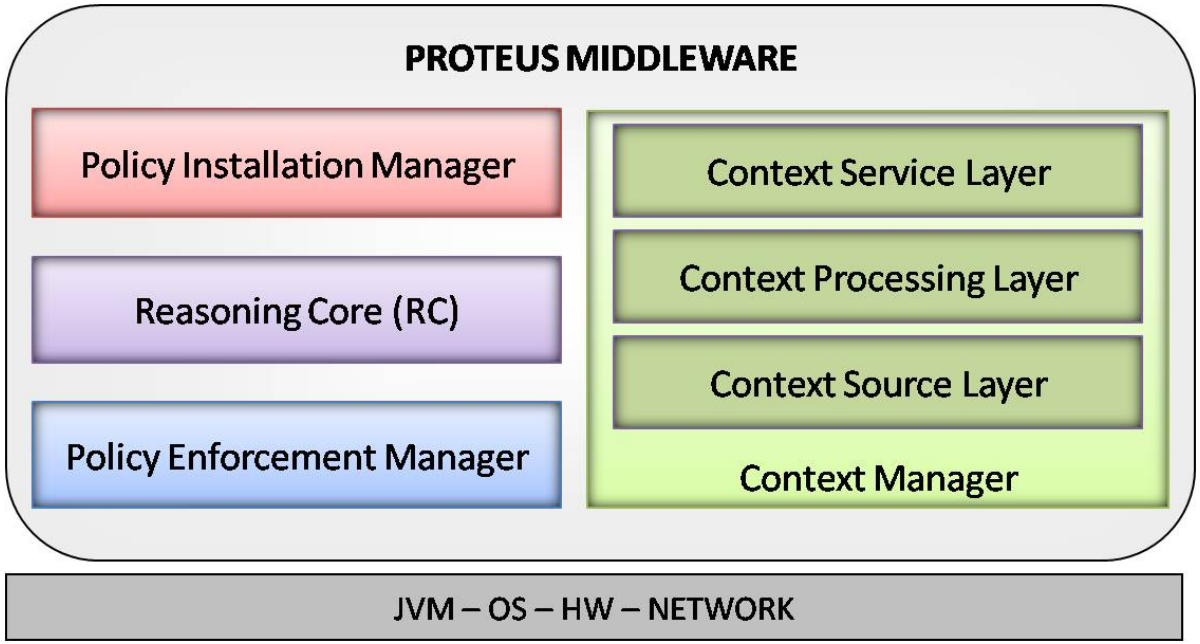
QoC-based Policy Evaluation

- Policies are assigned a quality threshold
- Current states are provided with different quality values (combining quality values of single context assertions)

- Proteus activates only policies matched by a current state that
  1. matches the policy protection context AND
  2. has a quality value higher than the policy threshold

- Policy thresholds might depend on sensitivity of the accessed resource, type of action, owner/requestor security properties
  - Variable levels of security can be obtained by adjusting quality thresholds

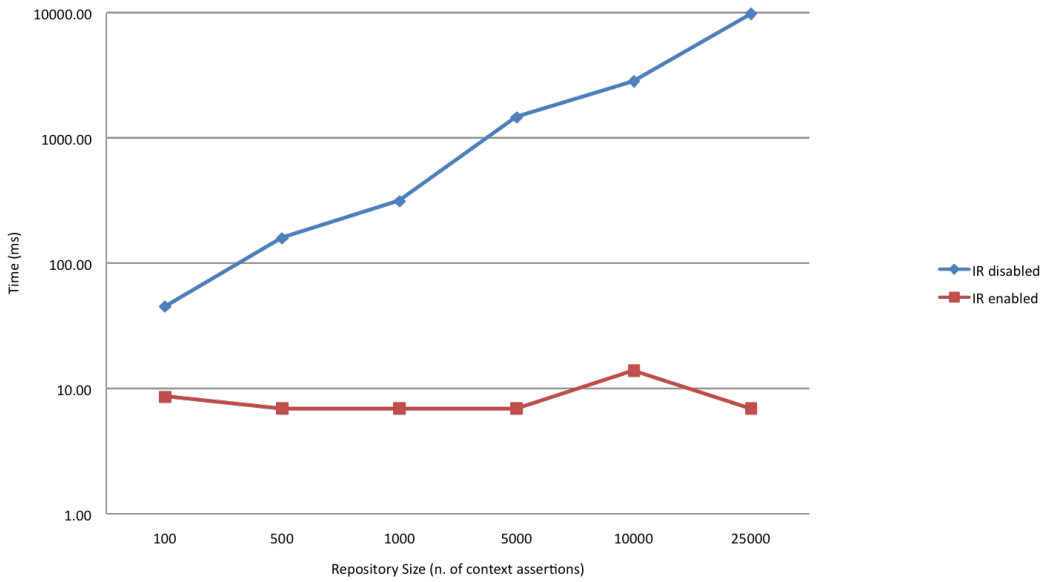
Proteus Middleware Architecture



- OWL-DL to represent contexts and policies
- Java first prototype extended to support QoC
  - Pellet 1.5 DL reasoner with incremental reasoning, via OWL API & SPARQL
  - Contory Context Source & Proteus Context Service modules

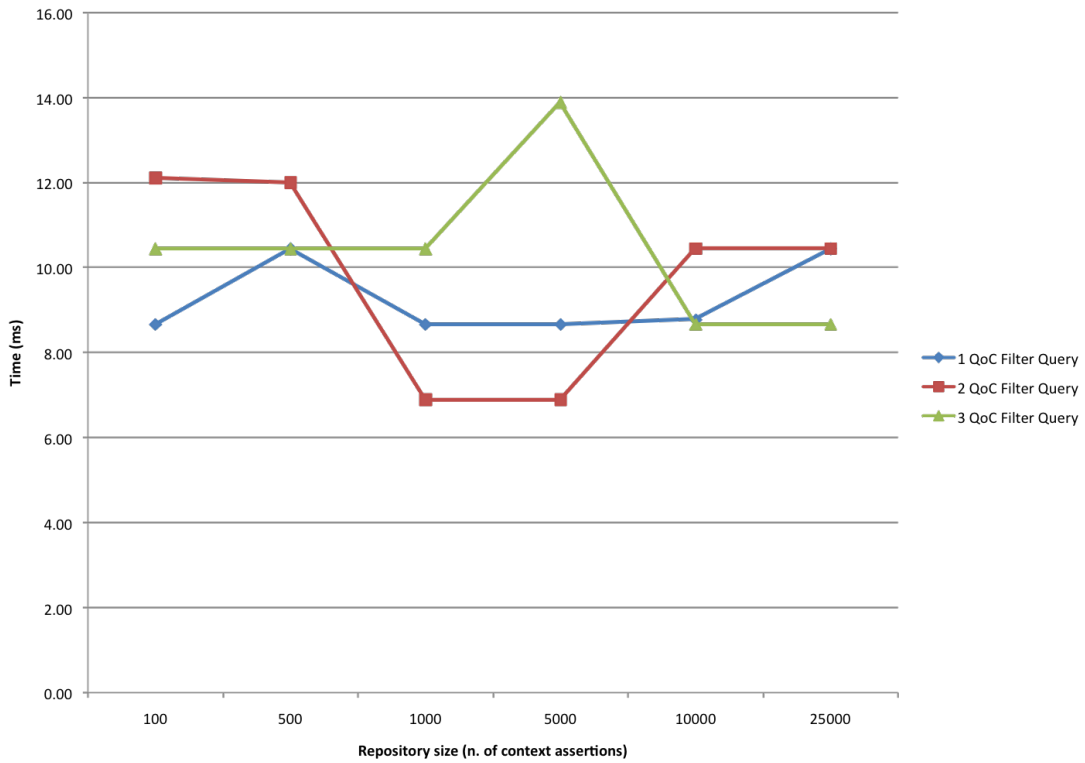
Prototype Evaluation – Context Repository Update

- Improved performance with Pellet incremental reasoning
  - Times to add context assertions show little dependence on repository size
    10 ms with 25k stored context assertions
  - No real advantage in context assertion removal



Prototype Evaluation – Context Query

- QoC constraints reduce query response time by limiting the number of retrieved context assertions
  - QoC-constrained queries not dependent on repository size
    $\longrightarrow$ increased efficiency



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Summary

- Proteus is a QoC-aware access control framework
  - QoC modeling & reasoning explicitly account for QoC impact on security
  - QoC improves efficiency by discarding unreliable context information

- Ongoing & Future Work
  - QoC/context information management & storage optimizations
  - Integration with existing QoC calculation frameworks/tecnhiques
  - Evaluation of usability of the proposed approach