Policy Aware Systems
Some open research issues

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Outline I

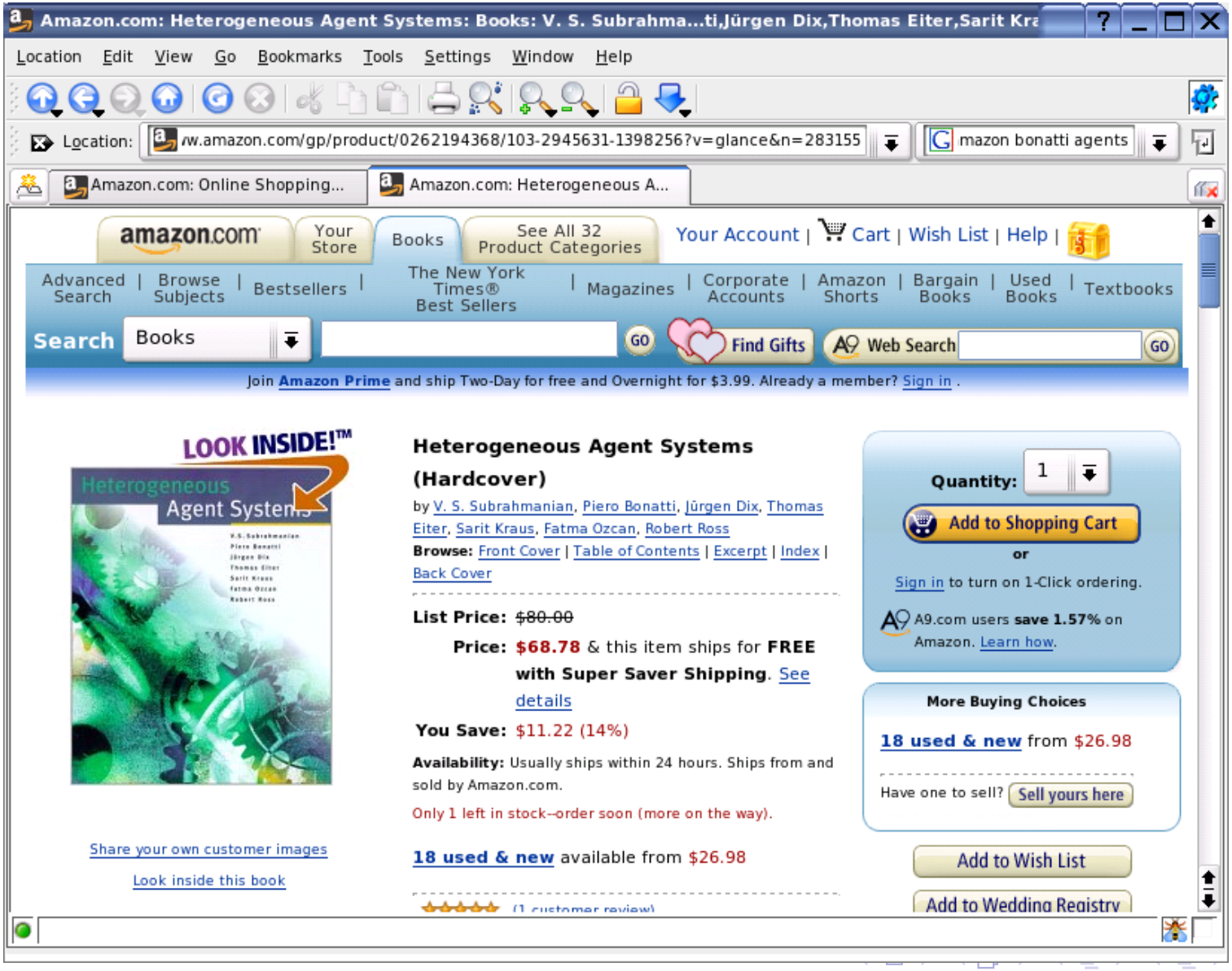
Credentials for Open Systems

Digital credentials constitute the main approach to access control for open systems

- Reliable
  - Unforgeable (cryptographic techniques)
  - Ownership can be checked (with *challenges*)
  - ...
- Scalable
  - There can be many domain-specific certification authorities...
- Privacy-oriented
  - Can represent properties of individuals
  - Without necessarily disclosing their *identity*

Widely adopted in basic tools such as *SSL*. Researchers are more ambitious

Scenario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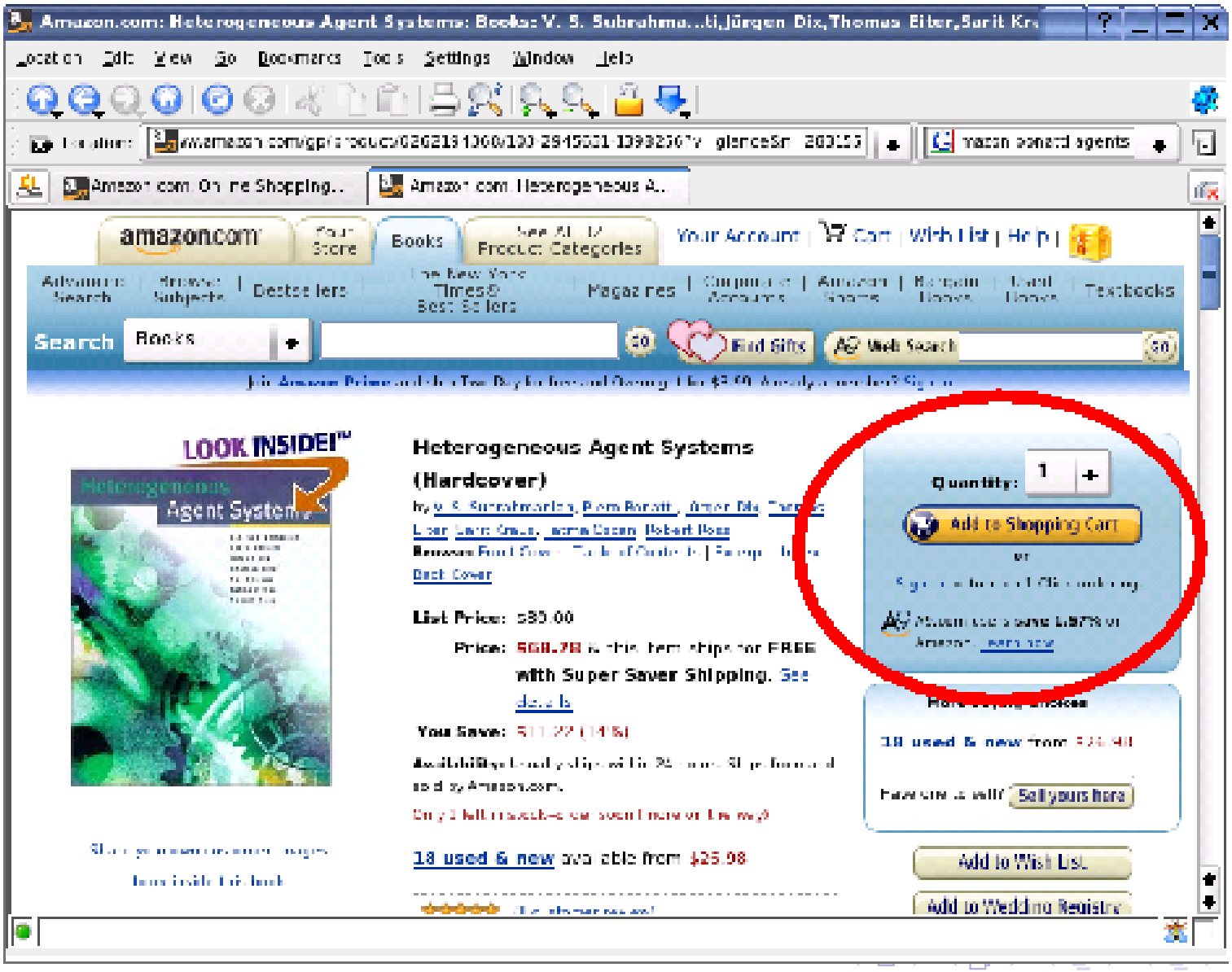
Scenario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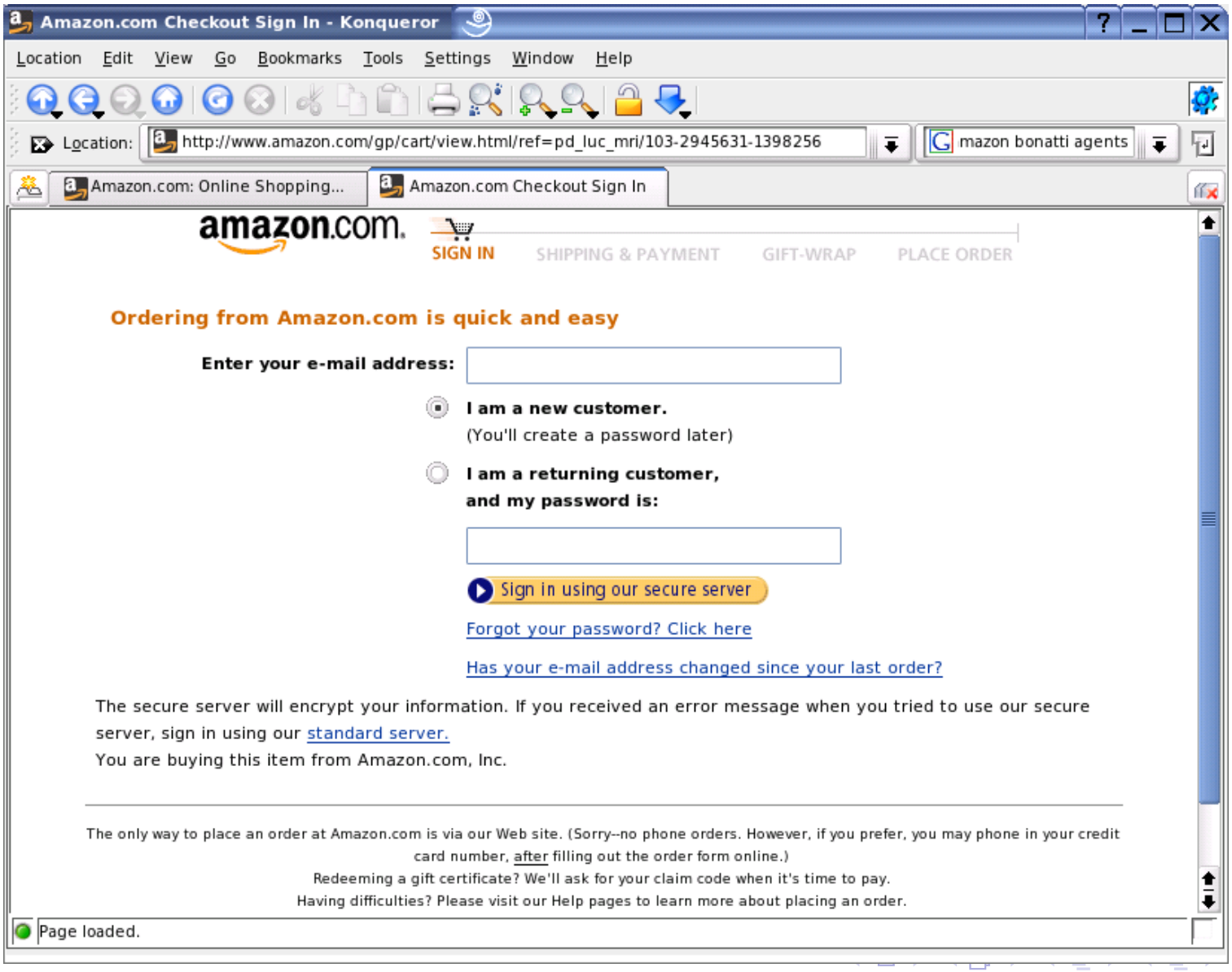
Scenario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Ordering from Amazon.com is quick and easy
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(You'll create a password later)
I am a returning customer,
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Scenario: Scalability and usability issues

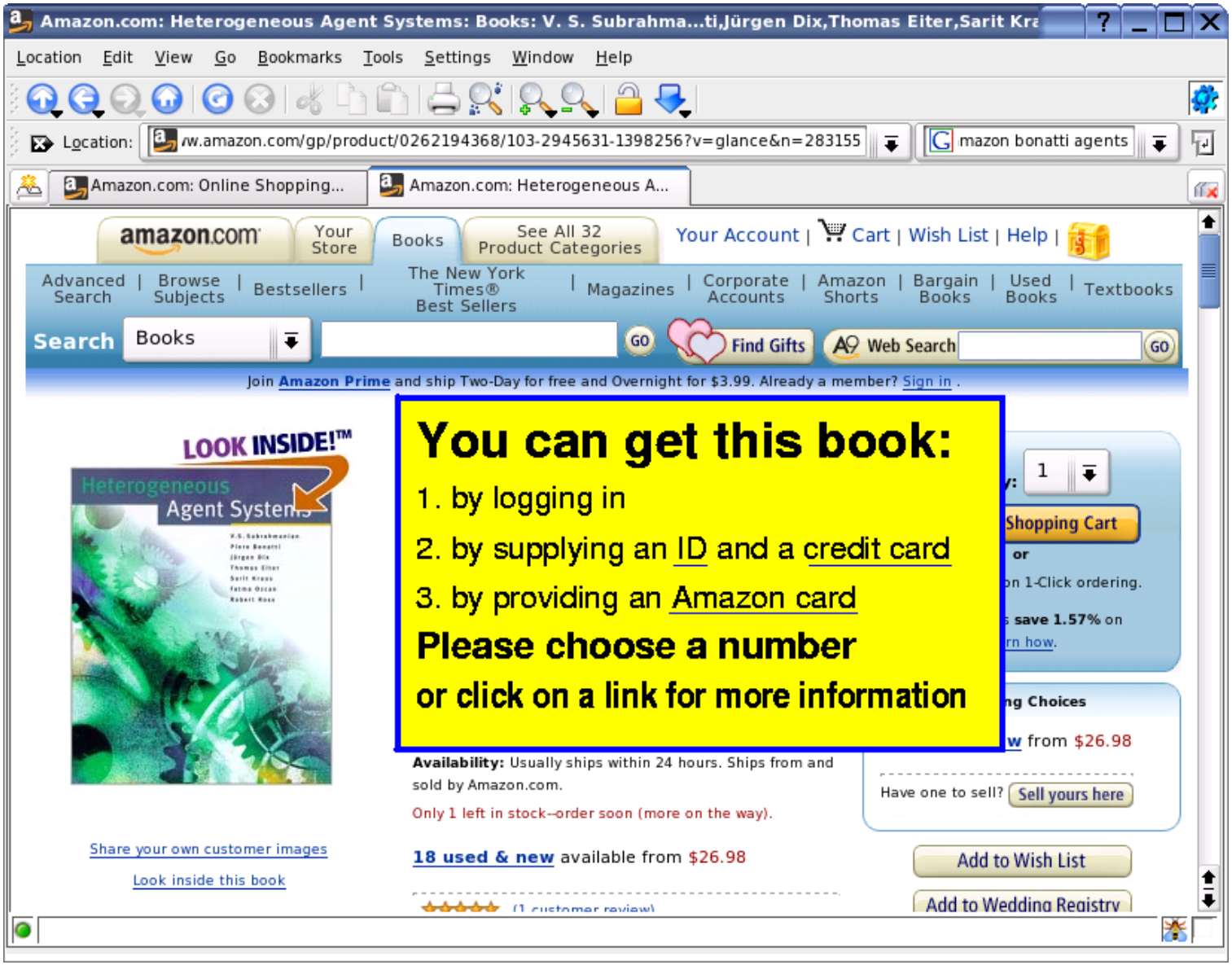
Similar considerations hold for systems based on

- MyProxy, Kerberos, CAS
- oriented to "localized" navigation

In the absence of more flexible identification methods:

- Web services have to keep accounts for all customers
- Users have to create accounts all the time
- Articulated business policies are discouraged

Scenario: Scalability and usability issues

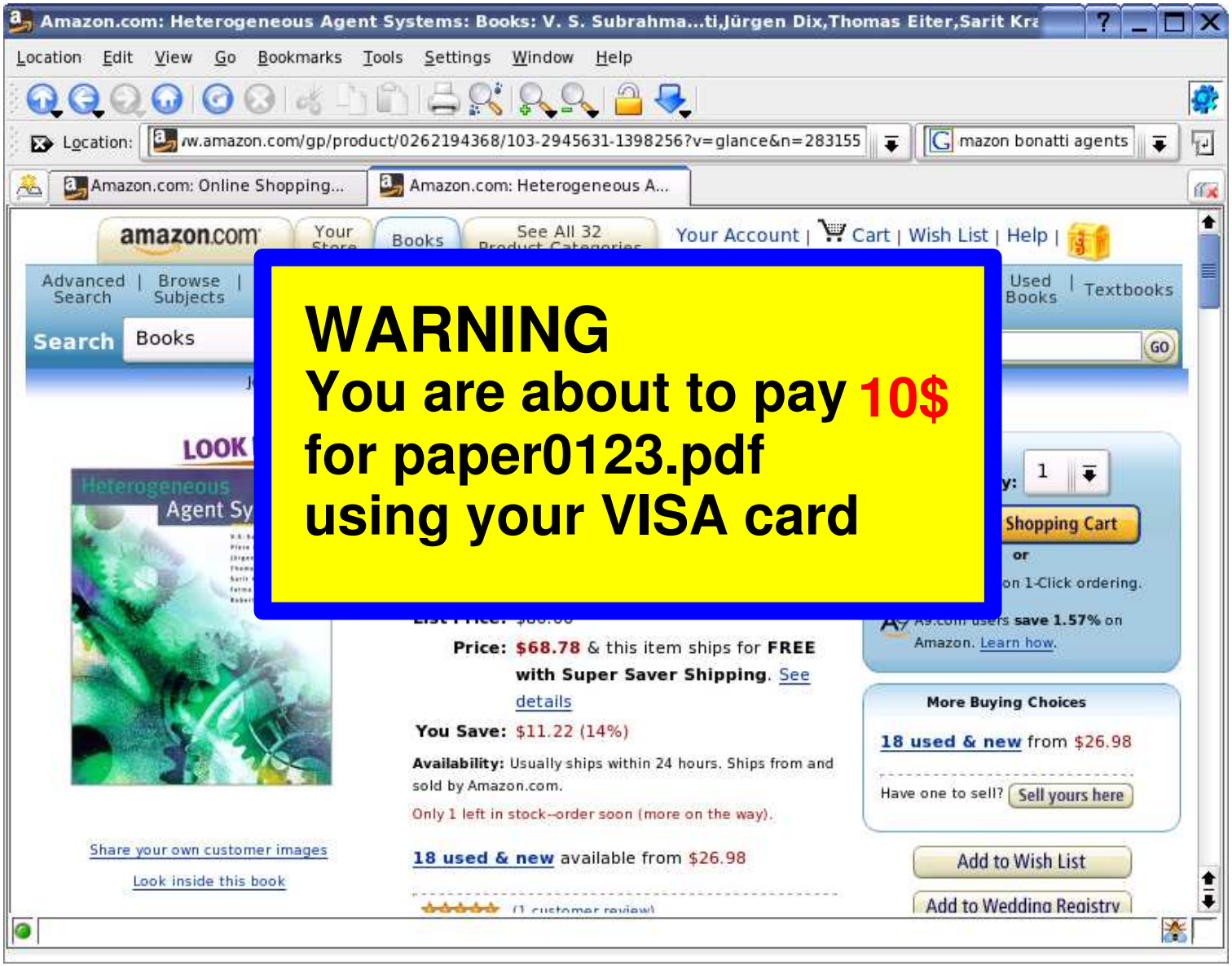


Scenario: Scalability and usability issues

What one would really want:

- Suppose the Amazon card gives you free access to some products
- If you have it, you want to use it automatically
  - click on the purchase button, and that's it
- If you don't you may want to see something like the next figure

Scenario: Scalability and usability issues



Ubiquitous Computing Scenarios

Similar desiderata:

- Travellers connect to airport lounge services
  - such as network, printers, content services, ...

  using
  - frequent flier cards
  - pre-payed cards
  - credit cards
  - employee credentials (government, airlines, ...)
  - ...

- In a transparent way (well, as much as possible)

How to ask for credentials

One by one (e.g. PeerTrust)

- slow (more messages)
- unnecessary disclosures
  - after sending off your credit card you realize that you should also send an id credential that you don't have
- unnecessary messages (even slower)

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All the alternatives at once

- less messages, less unnecessary disclosures

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- slow (more messages)
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  - after sending off your credit card you realize that you should also send an id credential that you don't have
- unnecessary messages (even slower)

All the alternatives at once

- less messages, less unnecessary disclosures
- combinatorial explosion: *an id and a credit card* becomes
  - passport and VISA
  - passport and Mastercard
  - ...
  - student-card and VISA
  - ...

Send the policy

As a compact but exhaustive request formulation (e.g. Protune)

Informal policy

1. allow purchase **if** the customer sends an *id* and a *valid credit card* **or**...
2. an *id* can be a passport, a student-card, ... issued by a *recognized CA*
3. a *valid credit card* is issued by VISA or ... and it is not *expired*
4. ...

The client then searches its portfolio for credentials that - together with the (formal) policy - entail *allow purchase* (an *abduction problem*)

Proposed for the first time in [CCS 2000]

Formal policy in Protune

Something similar to:

```
allow(purchase,Item) ←
    id(ID),
    credit_card(CC),
    ID.name = CC.holder.
...
credit_card(X)  ←
    credential(X),
    accepted_cc(X.issuer).

accepted_cc('VISA').
accepted_cc('Mastercard').
...
```

Formal policy in Protune

Something similar to:

```
allow(purchase,Item) ←                    (decision predicate)
    id(ID),
    credit_card(CC),
    ID.name = CC.holder.
...
credit_card(X)  ←
    credential(X),
    accepted_cc(X.issuer).

accepted_cc('VISA').
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Formal policy in Protune

Something similar to:

```
allow(purchase,Item) ←
    id(ID),
    credit_card(CC),
    ID.name = CC.holder.
...
credit_card(X)  ←
    credential(X),                    (provisional predicate)
    accepted_cc(X.issuer).

accepted_cc('VISA').
accepted_cc('Mastercard').
...
```

Formal policy in Protune

Something similar to:

```
allow(purchase,Item) ←
    id(ID),
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credit_card(X)  ←
    credential(X),
    accepted_cc(X.issuer).

accepted_cc('VISA').
accepted_cc('Mastercard').
...
```

Flora-like O.O. syntax

Relationships with Semantic Web

Informal policy

1. allow purchase **if** the customer sends an *id* and a *valid credit card* **or**...
2. an *id* can be a passport, a student-card, ... issued by a *recognized CA*
3. a *valid credit card* is issued by VISA or ... and it is not *expired*
4. ...

- The definitions of *id, valid credit card, recognized CA* etc. constitute a simple *ontology*
- The server shares its ontology with the client
  - basic shared knowledge: rule semantics and X.509
  - underlying logic: function-free Horn clauses
  - complex shared domain ontologies are not a prerequisite
  - feasible *today*

Privacy policies

Credentials may contain *sensitive information*

- users should not explicitly authorize *each* disclosure
- *release policies* are needed
- that can be treated like access control policies [CCS 2000]

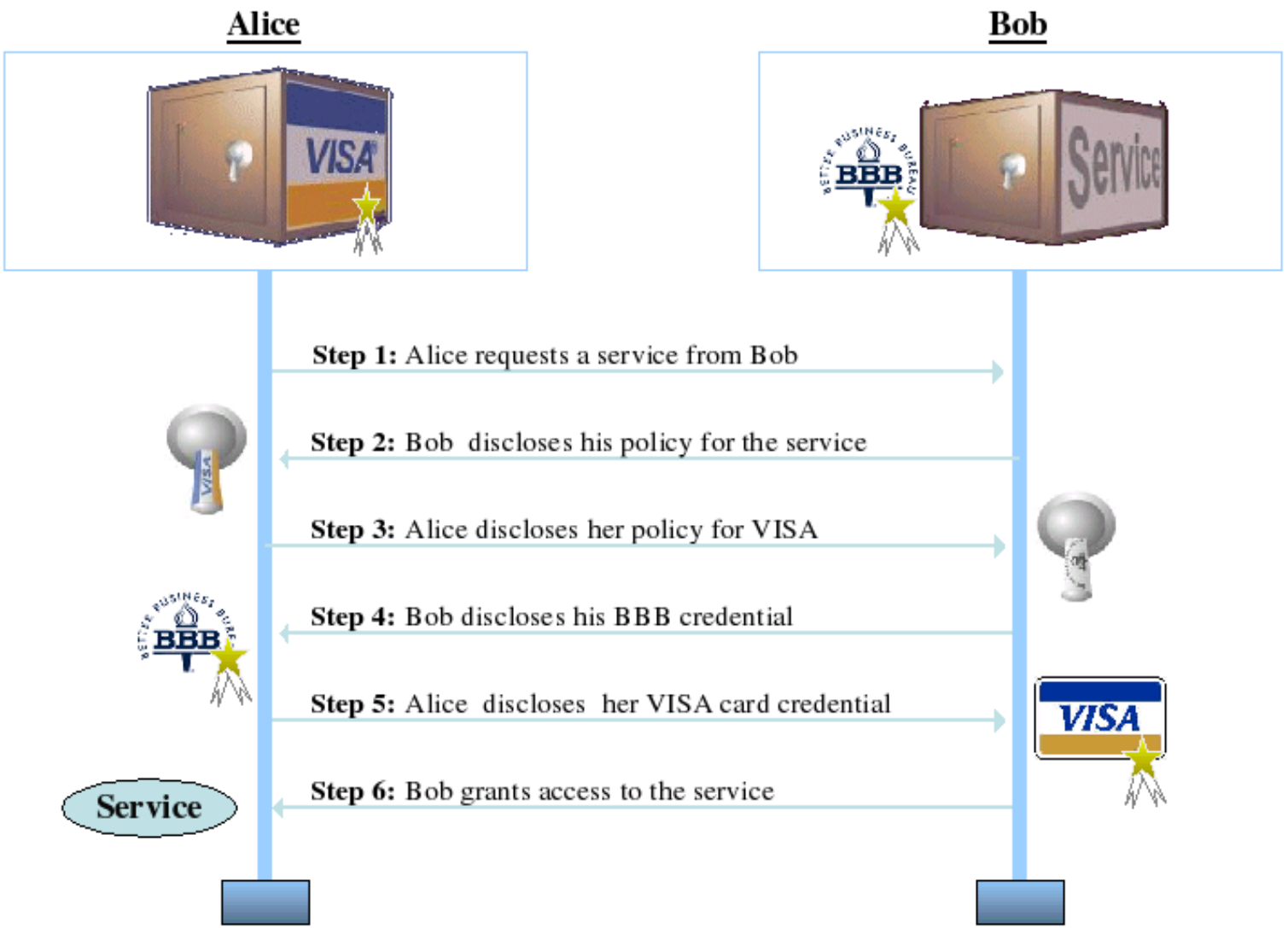
Informal privacy policy

1. allow credit card disclosure **if** the server joins the Better Business Bureau program
2. allow student-id disclosure (always)
3. ...

In response to a credential request the client may issue a counter-request

$\Rightarrow$ Trust Negotiation

A negotiation scenario



Multi-party negotiations

Third parties may be needed to:

- check credit card validity
- store credentials
- give special permissions
- ...

Protune metapolicies may be used to specify whom is responsible for what, e.g.

$$\texttt{credential(C).actor:serverXY} \leftarrow \texttt{C.type:student\_id}$$

means that `serverXY` is to provide student ids

Some technical issues

- Policy protection
- Negotiation length
- Negotiation success
- Minimizing information disclosure
- Provisional policies (actions)

Policy protection

The policy itself is confidential

- it may reveal agreements between companies
- it may reveal private information
  1. only my best friend can see my pictures
  2. my best friends are ...
- definition of *correct user-password pairs*...

Policies have to be protected

- by hiding some rules
- by *sanitizing* others

$\Rightarrow$ Policy Filtering (before each disclosure)

Policy protection in Protune

The sensitivity of policy rules and predicates is declared with suitable metapolicies:

- A rule with name [r] can be protected by asserting

  `[r].sensitivity:private`

- Sensitivity may depend on further conditions, as in

  `[r].sensitivity:public` $\leftarrow$ `authenticated(User)`

  In this way, more rules can be disclosed as the level of trust increases during negotiation
- Predicates can be protected in a similar way, e.g.

  `passwd(User,Pwd).sensitivity:private`

Further features are described in REWERSE report I2-D2

Sanitizing credential requests

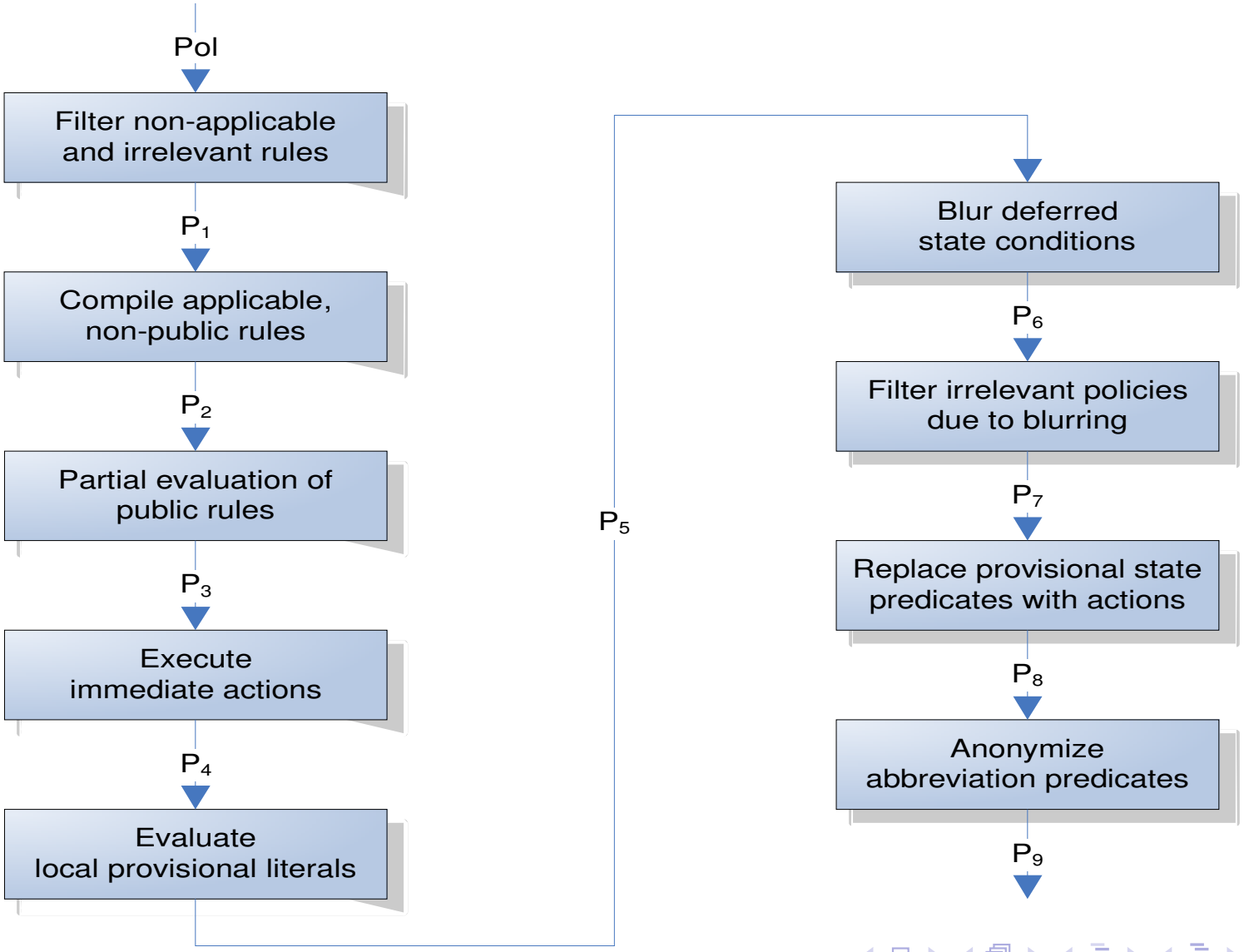
Private rules can be applicable or non-applicable

- applicable rules are evaluated
- only their results are sent off
- non-applicable rules are discarded
- rules with a private predicate in the head are private

Private *state* predicates are blurred

- private atoms are replaced with a fresh propositional symbol

Policy filtering



Negotiation length

In general, difficult to predict

- the server may issue a counter-counter-request, and so on
- protected policies are disclosed incrementally
  - as the other peer sends more credentials

? Techniques for estimating max length

? Useful bounded protocols

? Useful restricted *policies*
  - 2-step disclosure [CCS 2000]
  - unilateral policies (the server releases no credentials)
  - transparent (public) policies
  - too restrictive in many cases
  - REWERSE is working on more general cases

Negotiation success

Negotiations may fail because the peers hide part of their policies

- peers do not know how to fulfill the access control conditions

? any *local* conditions that guarantee success? (if the policies allow)

- little hope of being able to check *global* conditions on the policies of the involved peers
- current results: "if such & such disclosure sequence exists then..."
- *when* does it exist?
- REWERSE is working at improving these results

Minimizing information (sensitivity) disclosure

- some credentials are more sensitive than others
  - Safeway's discount card $\leq$ student-id $\leq$ credit card $\leq$ SSN ...
- even if all the policies are published, finding an optimal choice is computationally hard
  - precise characterization in the next REWERSE deliverable
- in general, when policies are protected no strategies guarantee optimality

? design languages for expressing preferences

? study reasonable negotiation strategies

? identify useful restricted cases that admit optimal strategies

  - and efficient algorithms, possibly *approximate algorithms*
  - some preliminary results in a forthcoming REWERSE report

Provisional policies (actions)

Sometimes policies have to execute actions

- log a request for audit purposes
- activate a workflow (e.g. for manual registration)
- ...

Credential themselves involve an action

- they can be requested and released and verified

In Protune further actions include

- declarations (unsigned)
  - accept a copyright/license agreement
  - login and password
  - ...
- application dependent action
  - e.g. connect to a URL

Example of declaration

Traditional authentication:

```
allow(access_site) ←
        declaration(username = N, password = P),
        has_passwd(N,P).
```

Declarations are treated like credentials during negotiation

- Declarations are *not* signed
- they are included in the current state without any cryptographic verification

Declarations can be supplied

- automatically, if the client's policy allows
- by filling in a form on a pop-up window

Metapolicies for actions

Specifying who is in charge of an action

```
credential(ID).actor:cmu_CA ← ID.type:student_id.
log(Request).actor:self
```

Specifying application-specific actions

```
log(_).type:provisional.
log(M).action: 'echo' + M + '> log_file'.
```

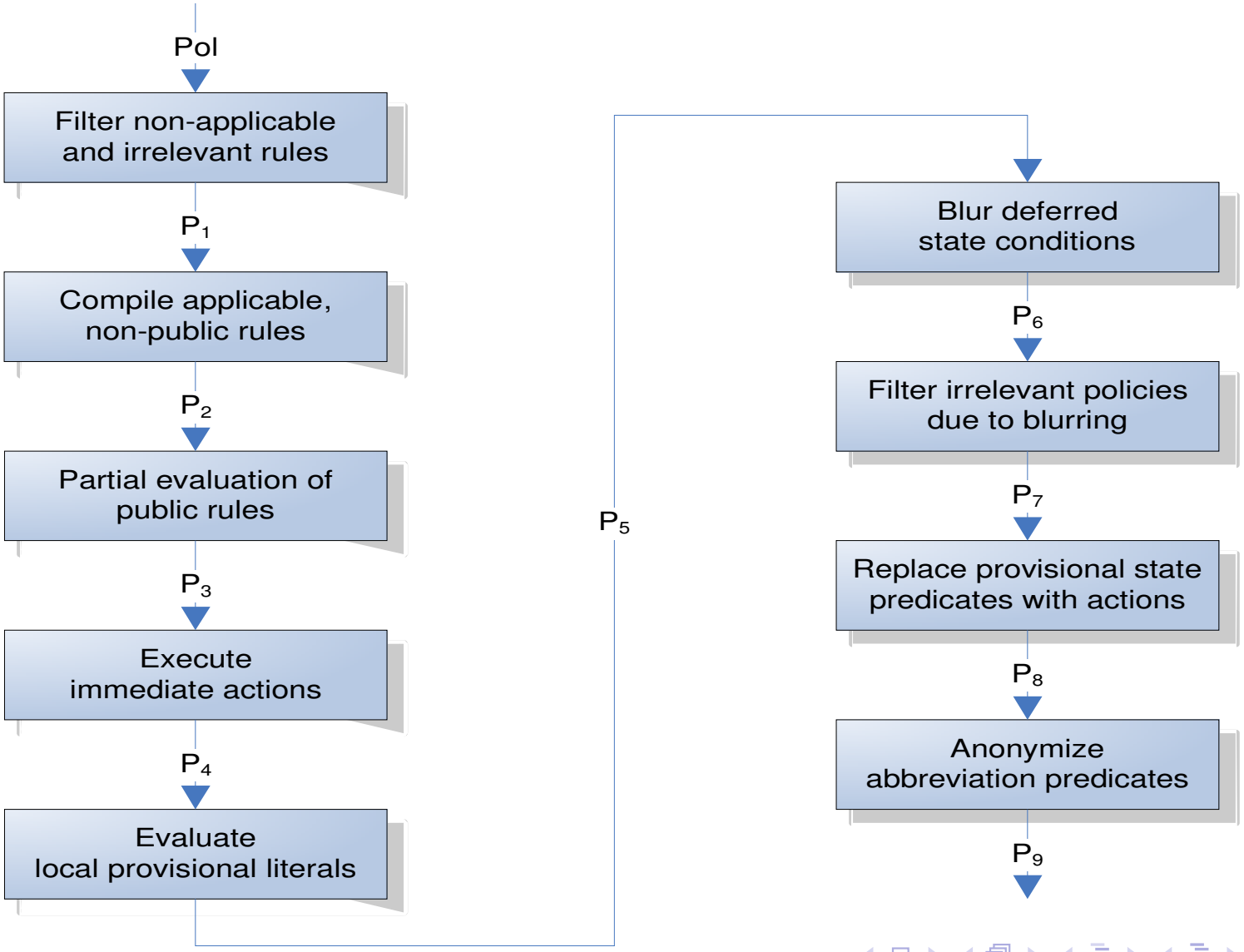
Specifying when an action should be executed

```
log(_).evaluation: immediate.
```

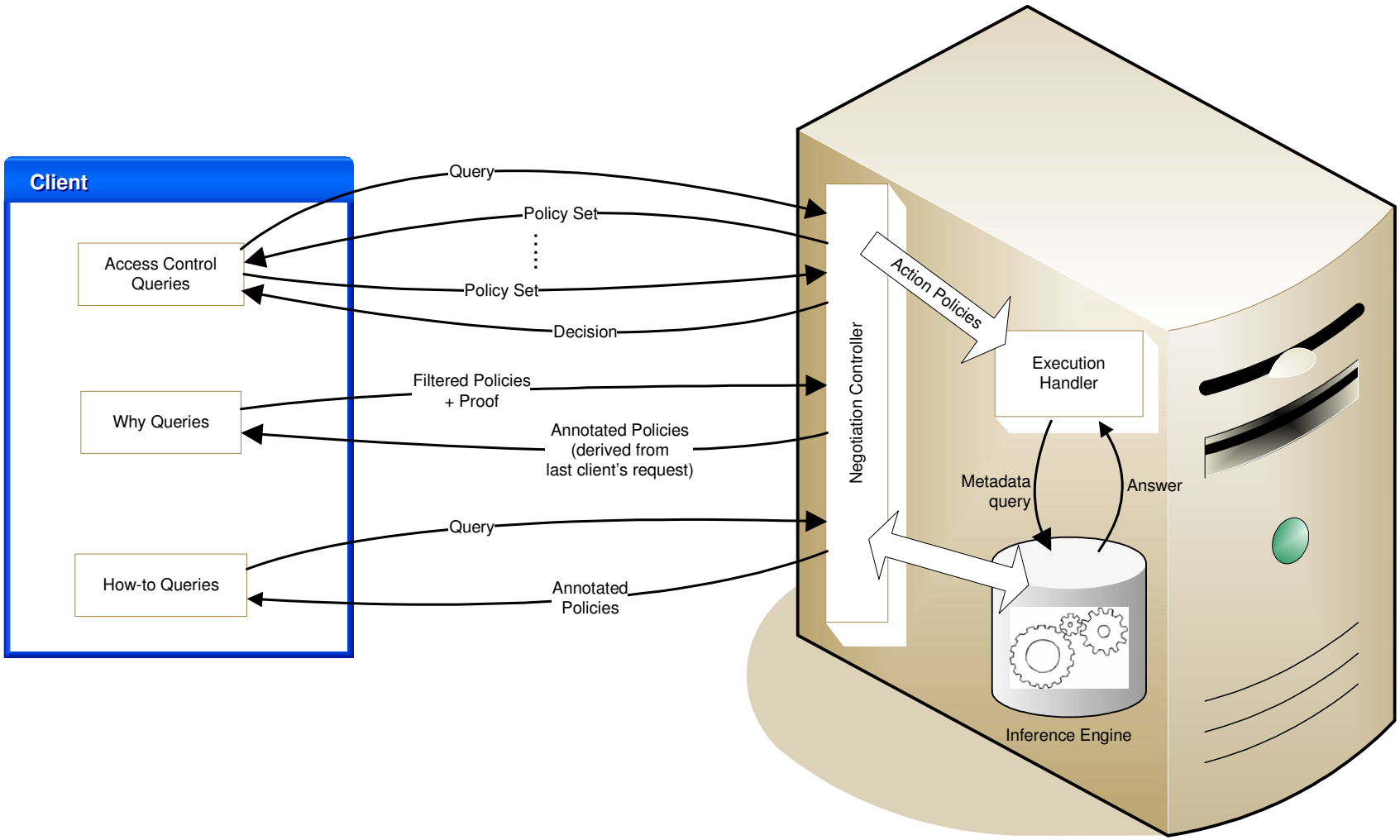
other values: `deferred`, `concurrent`

Plus some extra features (see REWERSE report I2-D2)

Interplay with filtering



Execution module



Event-Condition-Action rules

Current action semantics is vaguely Prolog-like

- when a predicate with actor `self` and evaluation `immediate` is enclosed in the filtered policy, it is evaluated

  `allow(Usr,Op,Obj)` ← `log(Usr+Op+Obj), ...`

- a bit less procedural than Prolog (parallel action execution)
- it fits well the abductive nature of negotiation

However many actions would be more naturally specified as ECA rules

- "... And by the way, whenever you get a request, log it"
- *incremental* policy formulation style
- not clear how to harmonize abductive and ECA semantics

Explanations

Users and policies

- Common users have little awareness and understanding of security and privacy policies
  - applied by their own system and by remote services
- this is a major source of security problems
  - a typical PC with default security settings is violated in $<$ 5min
  - with a careful setting the same machine resists for weeks
- there may be service usability issues
  - many first-time and occasional users in web and pervasive environments

Challenges

- a tradeoff is needed between protection and functionality
  - based on user's needs
  - generic policies typically won't work

  $\Rightarrow$ users should be able to personalize their policies
- similar arguments apply to privacy policies and credential release policies
  - risks are to be balanced with functionality and value

$\Rightarrow$ help users get better understanding of and control on policies

Strategies

- Education and dissemination through mass media
- Let users formulate their policies
  - user-friendly languages
  - based on simple concepts (no *cookies*)
- Explain policies and decisions
  - never say (only) *no*
  - negative answers should come with explanations and suggestions

Formulating policies

Graphical languages

- so far, not expressive enough [Winslett et al.]
- still interesting for *part* of the specifications e.g. user and object hierarchies

Controlled natural language

> *A user can browse directory "internal docs" if he provides a REWERSE credential*

- to be translated into Protune rules
- REWERSE is extending the Attempto system [Fuchs et al.]

Automated Explanations - Goals

Rich query set

- *how-to, why/why-not, what-if*

Quality comparable to 2nd generation explanation facilities

- remove irrelevant details
- high-level object identification
- ...

With improved failure explanations (*why not* queries)

- handling infinite failures

And low framework instantiation cost

- for every new application domain

Protune's explanations in a nutshell

- a hypertext
  - nodes corresponds to the entries of tabled LP engines (subgoal calls)

  $\Rightarrow$ can explain infinite failure
- local and global proof info to improve navigation ease
  - rules applicable to the current goal
  - answer substitutions for each of them
- intra- and inter-proof info
  - users can match anticipated proof outcomes with their own expectations and expand only the interesting parts of the proof
- explanations are focussed on what the user can do/should do/should have done
- irrelevant details are omitted using generic heuristics
- objects are denoted by means of their attributes (clusters)

Example: How-to query

to make sure that
it is allowed to download Resource
nothing needs to be done if
Resource is public
alternatively

```
allow(download(Resource)) ←
  public(Resource).

allow(download(Resource)) ←
  authenticated(User),
  has_subscr(User,Subscription),
  available(Resource,Subscription).
```

please make sure that
for some User
User is authenticated
where for some Subscription
User subscribed Subscription
and
Resource is available for Subscription

```
allow(download(Resource)) ←
  authenticated(User),
  paid(User,Resource).
```

alternatively ...

Example: Why-not query

I can't prove that
`it is allowed to download paper012.pdf` **because:**

```
allow(download(Resource)) ←
  public(Resource).

allow(download(Resource)) ←
  authenticated(User),
  has_subscr(User,Subscription),
  available(Resource,Subscription).

allow(download(Resource)) ←
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```

Example: Why-not query

I can't prove that
`it is allowed to download paper012.pdf` **because:**

`Rule [2] is not applicable:`

```
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  paid(User,Resource).
```

- Rule [1] removed by filtering

Example: Why-not query

I can't prove that
`it is allowed to download paper012.pdf` **because:**

`Rule [2] is not applicable:`
there is no `User` **such that**
`User is authenticated`

```
allow(download(Resource)) ←
  public(Resource).

allow(download(Resource)) ←
  authenticated(User),
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allow(download(Resource)) ←
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```

- Rule [1] removed by filtering
- Rule [2] partially omitted

Example: Why-not query

I can't prove that
`it is allowed to download paper012.pdf` **because:**

`Rule [2] is not applicable:`
there is no `User` **such that**
`User is authenticated`

and

`Rule [3] is not applicable:`
there is no `User` **such that**
`User is authenticated`
moreover
there is no `User` **such that**
`User paid for paper012.pdf`

```
allow(download(Resource)) ←
  public(Resource).

allow(download(Resource)) ←
  authenticated(User),
  has_subscr(User,Subscription),
  available(Resource,Subscription).

allow(download(Resource)) ←
  authenticated(User),
  paid(User,Resource).
```

- Rule [1] removed by filtering
- Rule [2] partially omitted
- Rule [3] involves 2 user-dependent conditions

Example: Why-not query

Predicate `authenticated/1` depends on `valid_id/1` ...

I can't find any `Cred` **such that**
`Cred is a valid id` **because:**

`Rule [6] is not applicable:`
`c321 is a credential`
with `type student-id`
and `issuer Open University,`
`student-id is an id`
but it is not the case that
`Open University is trusted for id`

```
valid_id(Cred) ←
    credential(Cred),
    Cred.type : T,
    Cred.issuer : CA,
    isa(T,id),
    trusted_for(CA,id).
```

Example: Why-not query

Predicate `authenticated/1` depends on `valid_id/1` ...

I can't find any `Cred` **such that**
`Cred is a valid id` **because:**

`Rule [6] is not applicable:`
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valid_id(Cred) ←
    credential(Cred),
    Cred.type : T,
    Cred.issuer : CA,
    isa(T,id),
    trusted_for(CA,id).
```

Here you see an example of a cluster

Architecture

Explanations need not be built on the server:

- the "server" sends its filtered policy together with predicate verbalization rules (and possibly the outcome of local predicates)

```
authenticated(X).explanation : [X,is,authenticated]
not authenticated(X).explanation : [X,is,not,authenti...
```

- the "client" constructs the tabled explanation structure and verbalizes the explanations

$\Rightarrow$ the computational cost of explanations can be moved to the clients

Final observations

- Explanations with a reasonable quality can be built with little instantiation effort
- and without overloading the server
- we are planning to assist the creation of literal verbalization by means of the natural language front-end for policy formulation
- some experimentation is needed to evaluate and refine the current heuristics
- there is space for improvements...

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- there is space for improvements...

NB: there are several other interesting TM issues that could not be discussed in this talk...

Questions?