Active Rules in the Semantic Web: Dealing with Language Heterogeneity

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Motivation and Goals

(Semantic) Web:

- XML: bridge the heterogeneity of data models and languages
- RDF, OWL provide a computer-understandable semantics

... same goals for describing behavior:

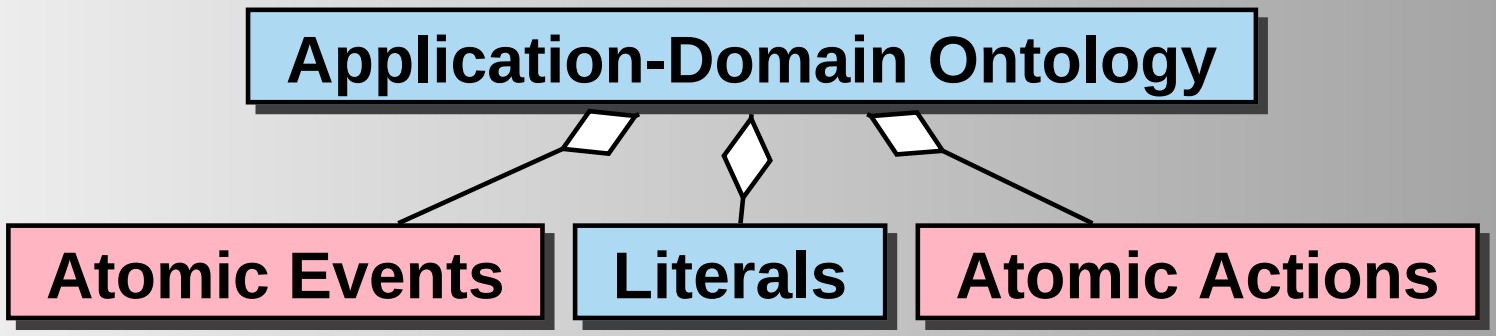
- description of behavior *in* the Semantic Web
- semantic description *of* behavior

Event-Condition-Action Rules are suitable for both goals:

- operational semantics
- ontology of rules, events, actions

Requirements

- Domain languages also describe behavior:



- combine application-dependent semantics with generic concepts of behavior
- Ontology
- Markup
- Operational Semantics

Analysis of Rule Components

... have a look at the clean concepts:
"On Event check Condition and then do Action"

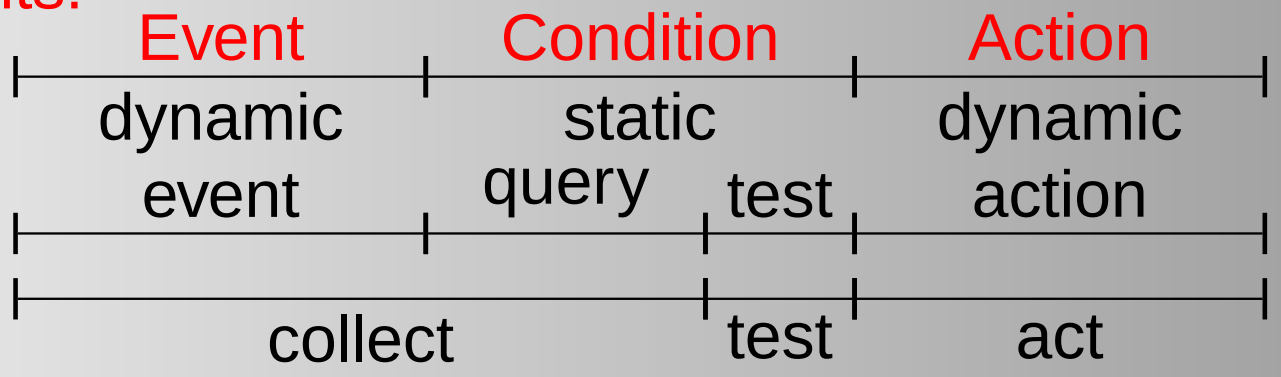
- Event: specifies a rough restriction on what *dynamic* situation probably something has to be done.
  Collects some parameters of the events.
- Condition: specifies a more detailed condition, including *static* data if actually something has to be done.
  $\Rightarrow$ evaluate a ((Semantic) Web) query.
- Action: actually *does* something.

Example

"if a flight is offered from FRA to LIS under 100E and I have no lectures these days then do ..."

Clean, Declarative “Normal Form”

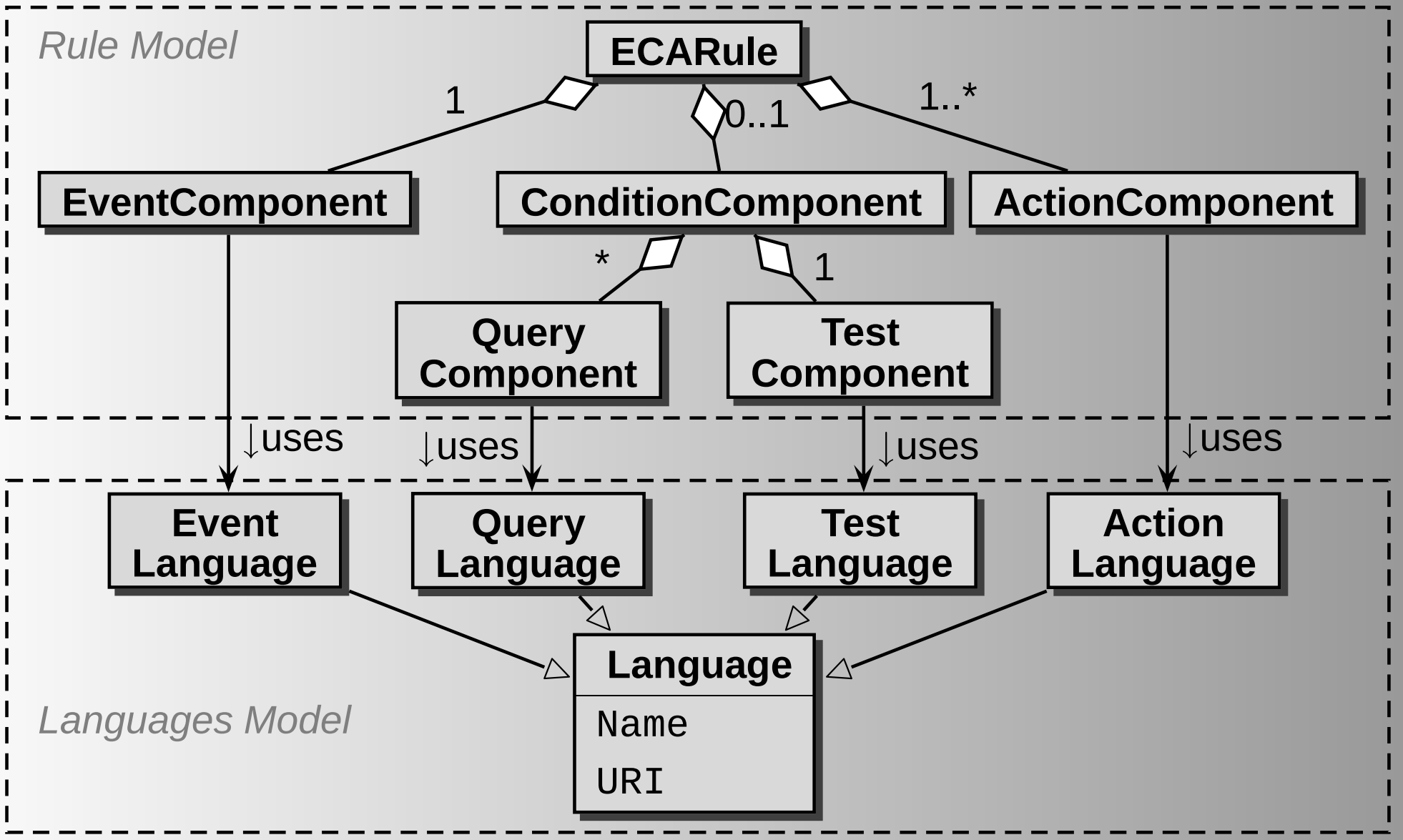
Rule Components:



- Event: detect just the dynamic part of a situation,
- Query: then obtain additional information by queries,
- Test: then evaluate a *boolean* condition,
- Action: then actually do something.

- Component sublanguages: heterogeneous
- Communication between components: logical variables

Modular ECA Concept: Rule Ontology



Rule Markup: ECA-ML

<!ELEMENT rule (event,query*,test?,action+) >

<eca:rule *rule-specific attributes*>
  <eca:event *identification of the language* >
    event specification, probably binding variables
  </eca:event>
  <eca:query *identification of the language* > <!-- there may be several queries -->
    query specification; using variables, binding others
  </eca:query>
  <eca:test *identification of the language* >
    condition specification, using variables
  </eca:test>
  <eca:action *identification of the language* > <!-- there may be several actions -->
    action specification, using variables, probably binding local ones
  </eca:action>
</eca:rule>

Example

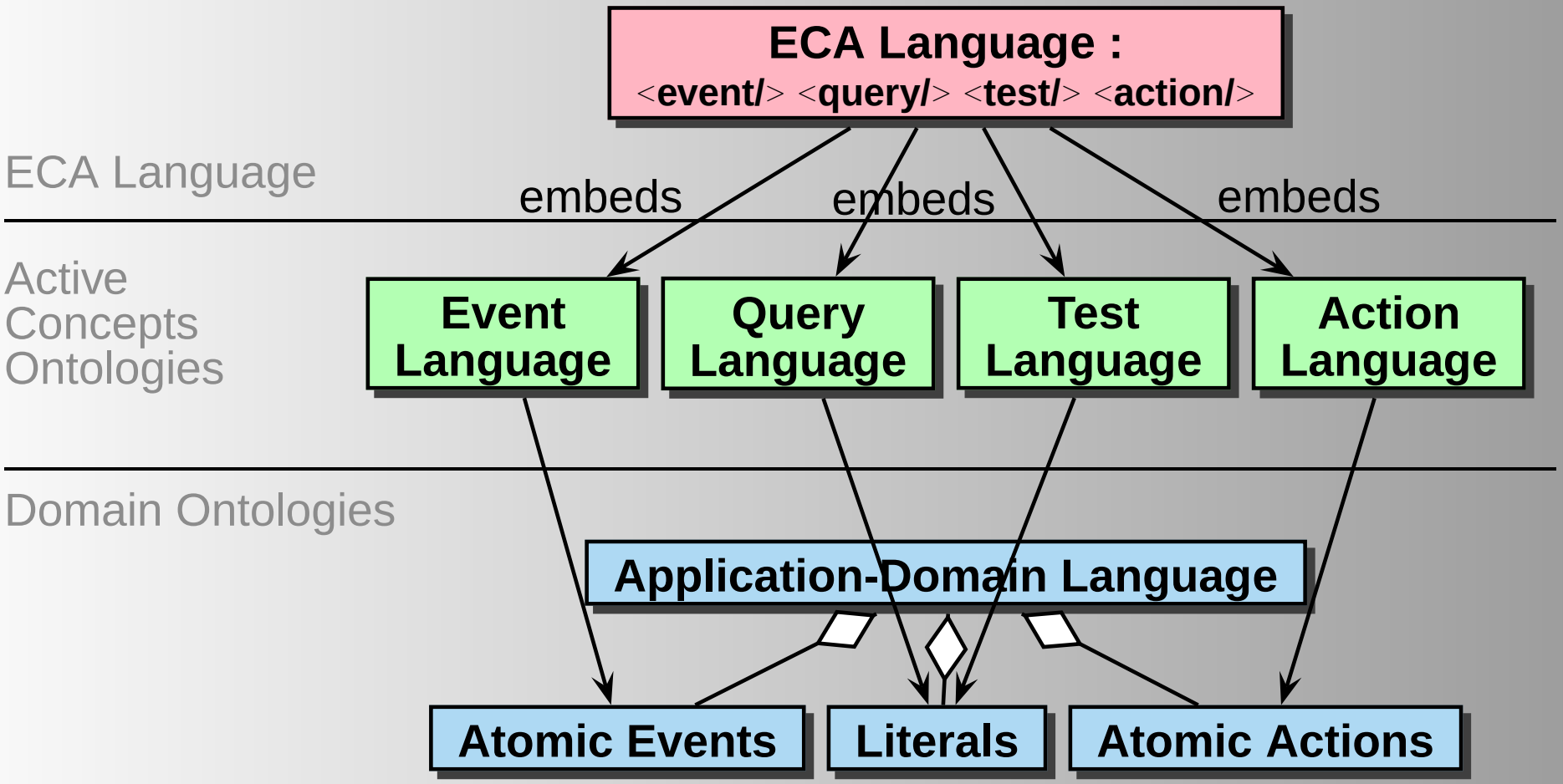
Sample Event:

```
<travel:cancel-flight flight="LH123">
    <travel:reason>bad weather</travel:reason>
</travel:cancel-flight>
```

```
<eca:rule>
  <eca:event xmlns:travel="www.travel.com" >
    <eca:atomic-event>
      <travel:cancel-flight flight="$flight"/>
    <eca:atomic-event>
  </eca:event>
  <eca:query> . . .  </eca:query>
  <eca:test> . . .  </eca:test>
  <eca:action > do something with $flight </eca:action>
</eca:rule>
```

Embedding of Languages

... there are not only atomic events and actions.

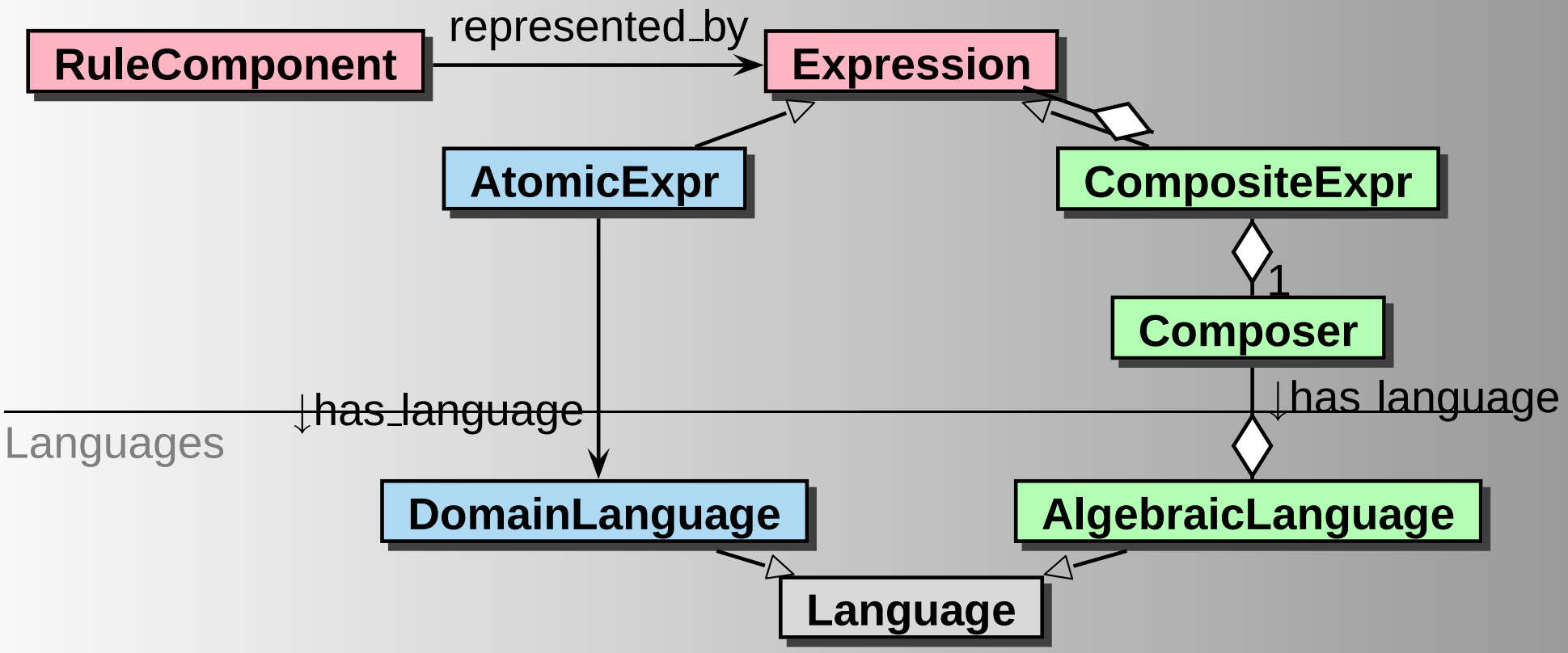


Sublanguages for Active Concepts

Algebraic Languages as a Generic Concept

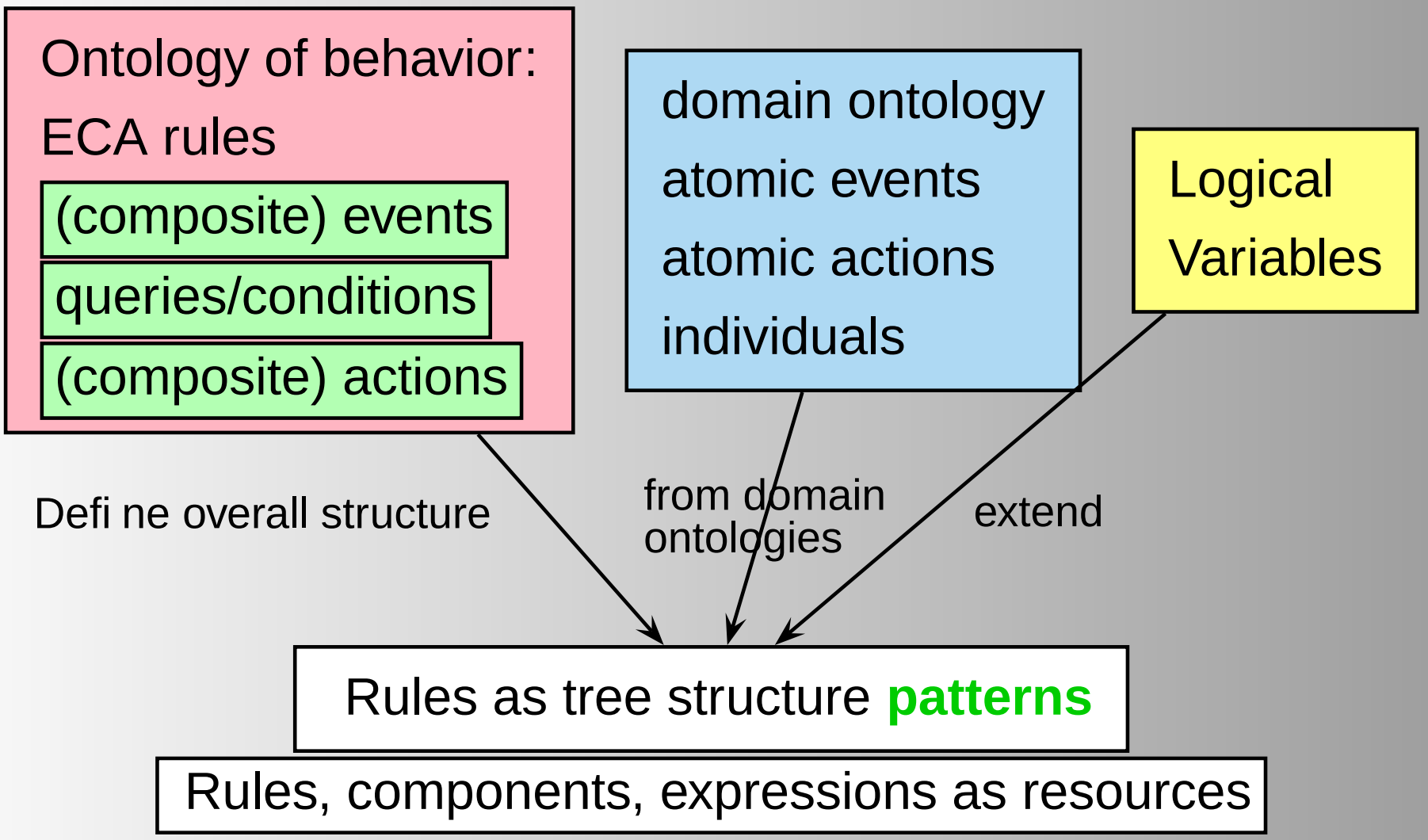
- Algebra terms: tree structures; expressions
  - events: event algebras (e.g. SNOOP)
  - queries
  - tests: boolean algebra
  - actions: process algebras (e.g. CCS)

Structure of Expressions



- tree corresponds to syntactical and semantical structure
- as operator trees: “standard” XML markup of terms
- RDF markup as languages
- every expression can be associated with its language

ECA Rule Markup



Sample Markup (Event Component)

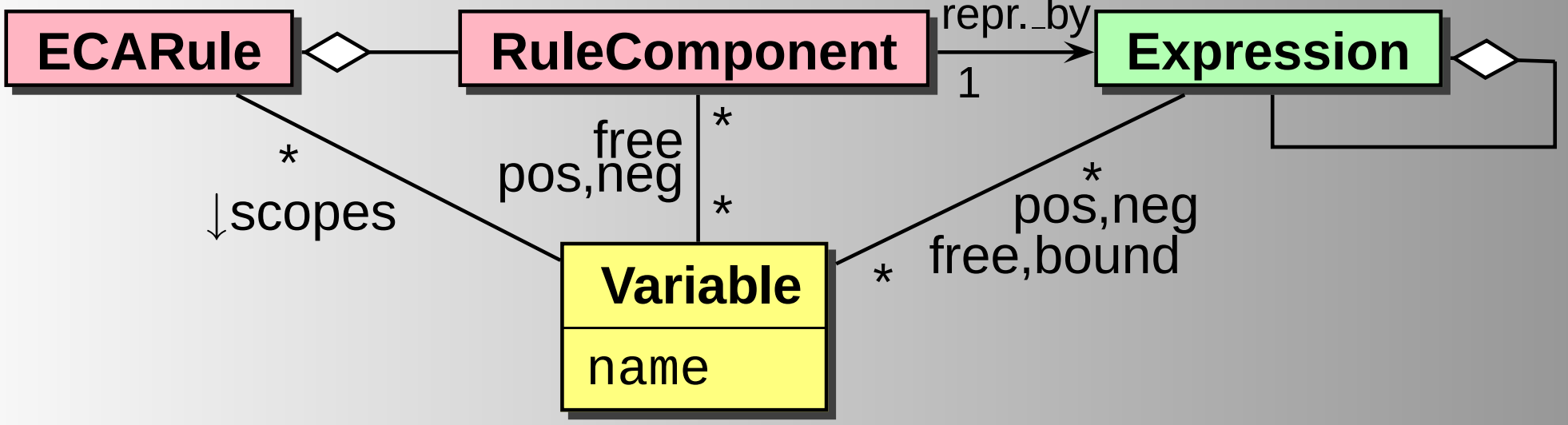
```
<eca:rule xmlns:travel="...">
  <eca:variable name="theSeq">
    <eca:event xmlns:snoop="...">
    <snoop:sequence>
        <eca:atomic-event>
          <travel:delay-flight flight="$Flight" minutes="$Minutes"/>
        </eca:atomic-event>
        <eca:atomic-event>
          <travel:cancel-flight flight="$Flight"/>
        </eca:atomic-event>
      </snoop:sequence>
    </eca:event>
  </eca:variable>
    :
</eca:rule>
```

binds variables:

- Flight, Minutes: by matching
- theSeq is bound to the sequence of events that matched the pattern

Rule Semantics

- Deductive rules: variable bindings Body$\rightarrow$Head
- communication/propagation of information by *logical variables*:
  $E \overset{+}{\rightarrow} Q \rightarrow T$ & A
- safety as usual (extended with technical details ...)



Operational Semantics of Rules

- Event: fires the rule
  - returns the sequence that matched the event
  - optional: variable bindings
- Query: obtain additional static information
  - returns the answer/set of answers
  - optional: for each answer, restrict/extend variable bindings (join semantics)
- Condition:
  - check a boolean condition, constrain variable bindings
- Action:
  - do something by using the variable bindings.

Binding and Use of Variables

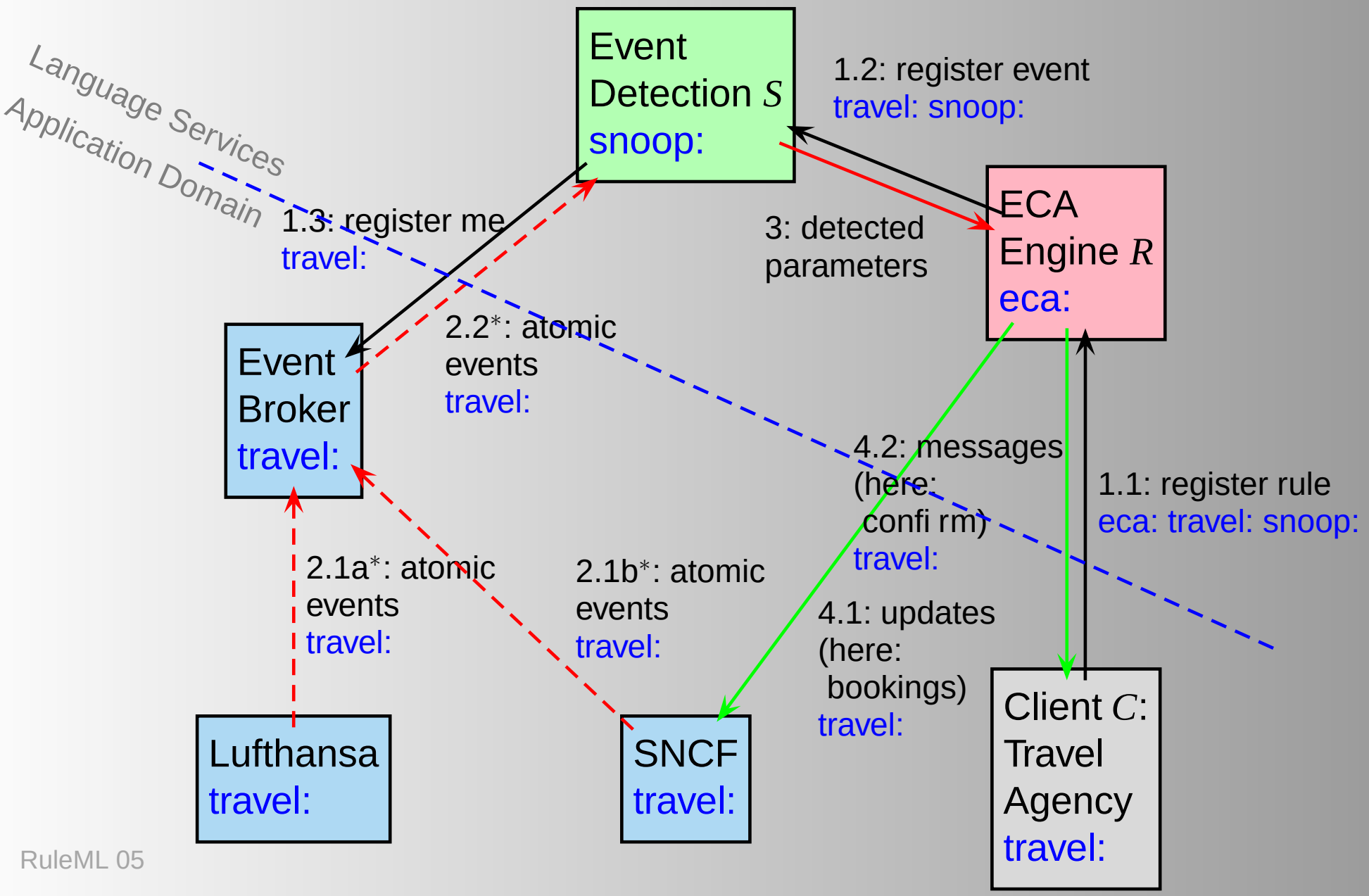
- Variables can be bound to values, XML fragments, RDF fragments, and (composite) events
- Logic Programming (Datalog, F-Logic): variables occur free in patterns.
  Markup uses XSLT-style
  <variable name="*var-name*"> and $*var-name*
  inside component expressions.
- functional style (Event algebras, SQL, OQL, XQuery): expressions return a value/fragment.
  ⇒ must be bound to a variable to be kept and reused.
  <variable name="*var-name*">*language-expr* </variable>
  on the rule level around component expression.

Engines – Service-Based Architecture

Language Processors as Web Services:

- ECA Rule Execution Engine employs other services for E/Q/T/A parts:
  nodes register their rules at the engines; processing is done by the engine
- dedicated services for each of the event/action languages
  e.g., composite event detection engines
- dedicated services for domain-specific issues:
  raising and communicating events, predicates, executing actions/updates
- query languages often implemented directly by the Web nodes (portals and data sources)

Architecture



Communication between Engines

ECA engine, event detection engines, query services etc.

- (sub)terms have well-defined results:
  variable bindings and/or result value
- XML markup for vertical communication of results and variable bindings:

```
<eca:variable-bindings>
  <eca:tuple>
    <eca:variable name="name" ref="URI"/>
    <eca:variable name="name"> any value </eca:variable>
      :
  </eca:tuple>
  <eca:tuple> . . . </eca:tuple>
      :
  <eca:tuple> . . . </eca:tuple>
</eca:variable-bindings>
```

Publications & Details

- REWERSE I5-D4: “Models and Languages for Evolution and Reactivity”: Everything + examples
- RuleML05: languages and their markup, communication and rule execution model
- ODBASE05: ontology of rules, rule components and languages, and the service-oriented architecture
- several additional details
- Prototype