Combining ECA Rules with Process Algebras for the Semantic Web

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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

ECA Rules

"On Event check Condition and then do Action"

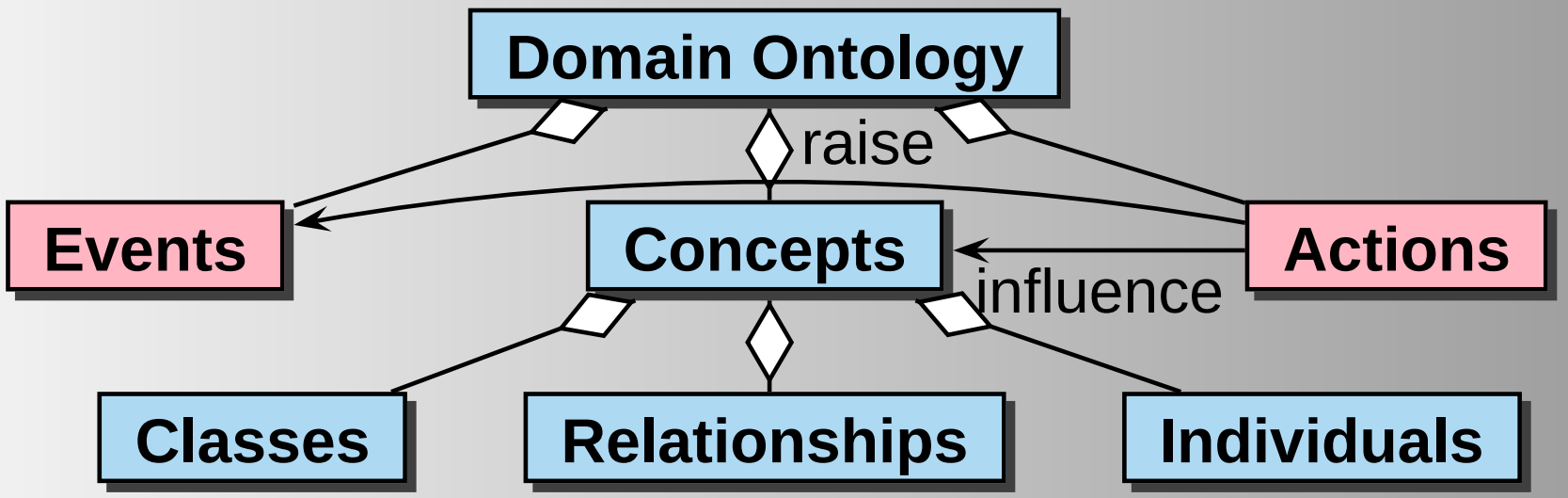
- paradigm of *Event-Driven Behavior*,
- modular, declarative specification in terms of the domain ontology
- sublanguages for specifying *Events*, *Conditions*, *Actions*
- *global* ECA rules that act "in the Web"

Requirements

- Ontology of behavior aspects
- modular markup definition,
- implement an operational and executable semantics

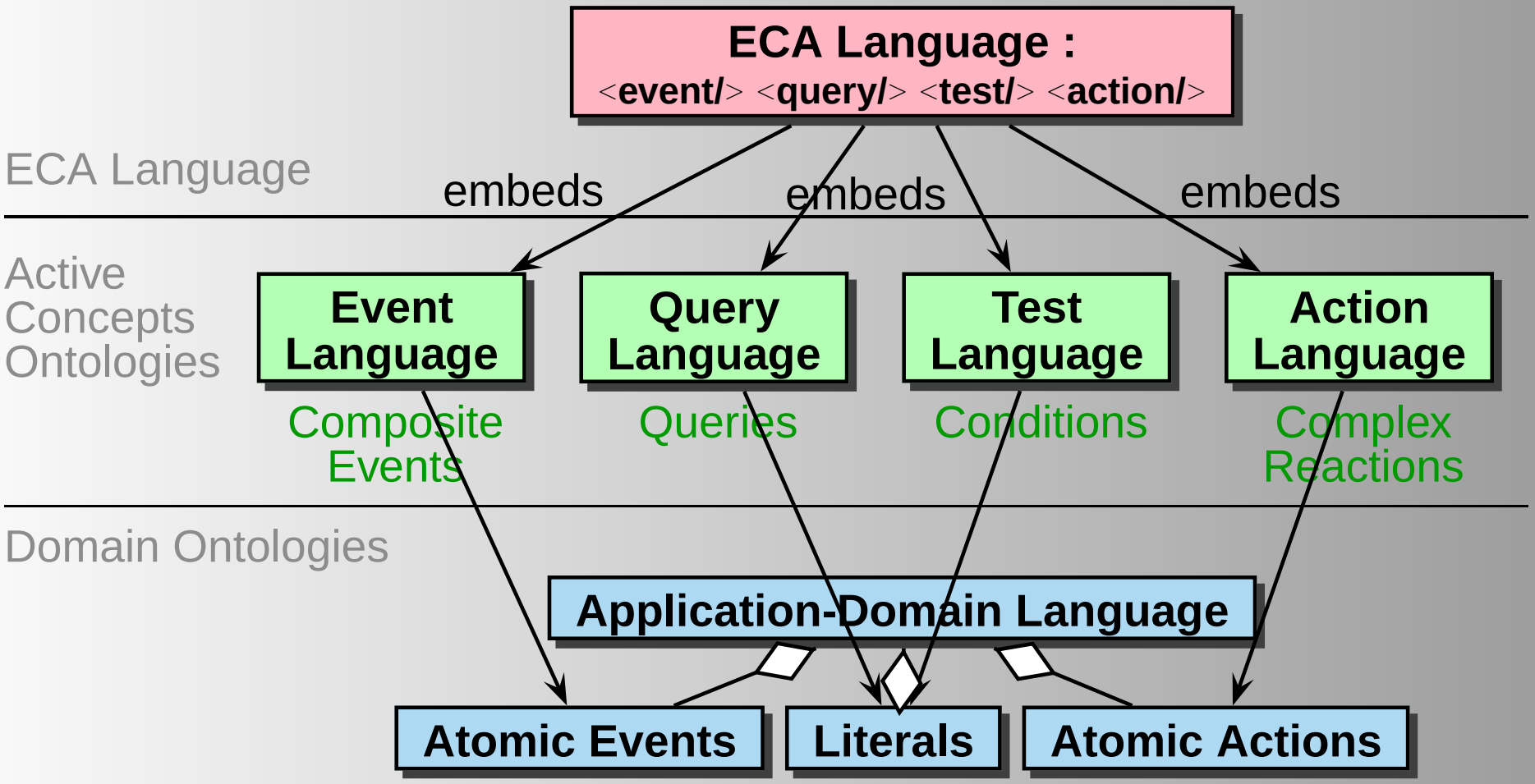
Events and Actions in the Semantic Web

- applications do not only have an ontology that describes static notions
  - cities, airlines, flights, etc., relations between them ...
- but also an ontology of events and actions
  - cancelling a flight, cancelling a (hotel, flight) booking,
- Domain languages also describe behavior:



Embedding of Languages

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



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

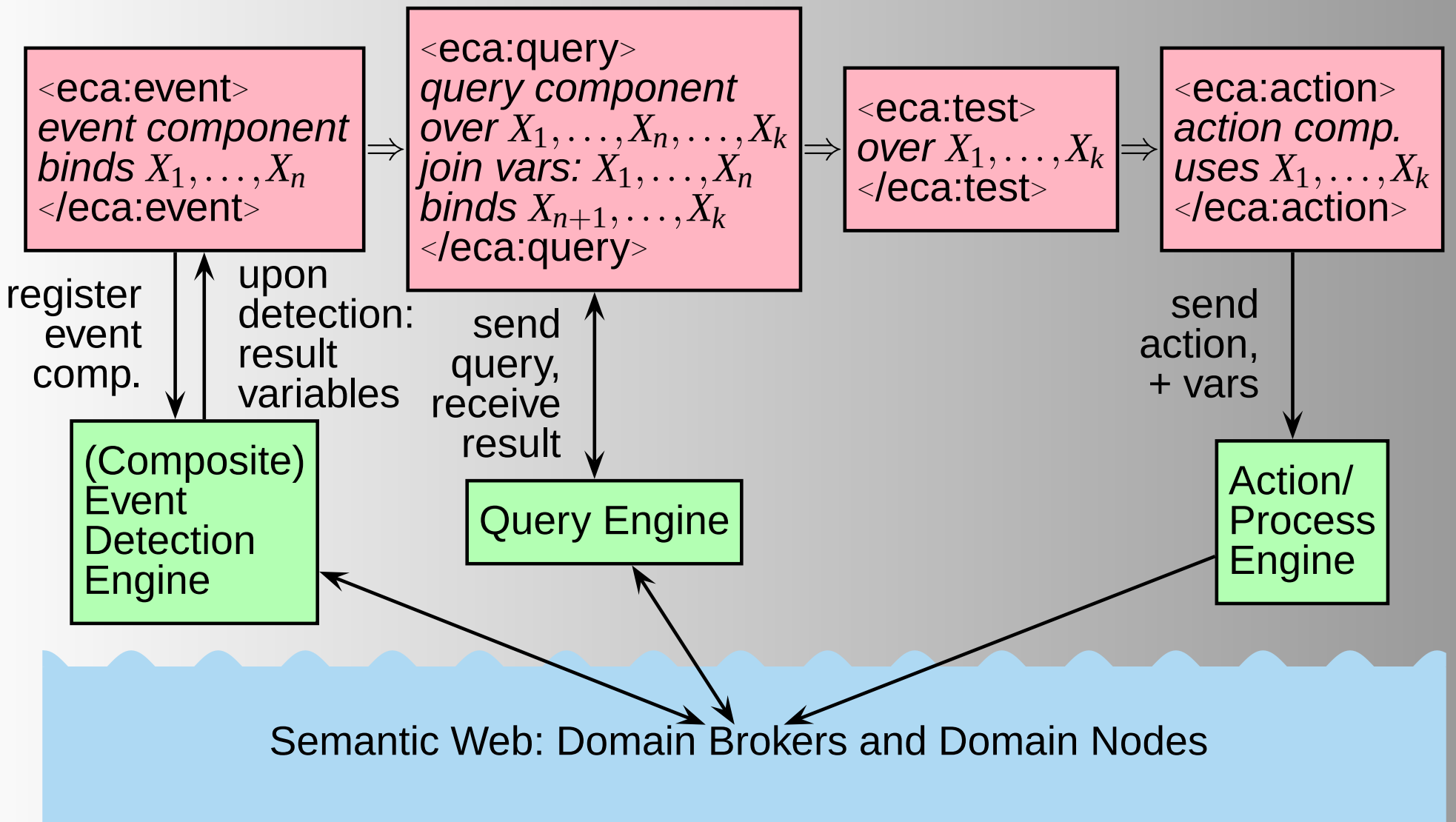
  </eca:action>

</eca:rule>

Binding and Use of Variables in ECA Rules

$action(X_1, \ldots, X_n) \leftarrow$

$event(X_1, \ldots, X_k),\ query(X_1, \ldots, X_k, \ldots X_n),\ test(X_1, \ldots, X_n)$



Rule Markup: Example (Stripped)

```
<!ELEMENT rule (event,query*,test?,action+) >
<eca:rule xmlns:travel="http://www.travel.de">
  <eca:event xmlns:snoop="http://www.snoop.org">
    <snoop:seq> <travel:delayed-flight flight="{$flight}"/>
      <travel:canceled-flight flight="{$flight}"/>  </snoop:seq>
  </eca:event>
  <eca:query>
    <eca:variable name="email">
      <eca:opaque lang="http://www.w3.org/xpath">
        doc("http://xml.lufthansa.de")/flights[code="{$flight}"]/passenger/@e-mail
      </eca:opaque> </eca:variable> </eca:query>
  <eca:action xmlns:smtp="...">
    <smtp:send-mail to="$email" text="..."/>
  </eca:action>
</eca:rule>
```

Active Concepts Ontologies

- Domains specify atomic events, actions and static concepts

Composite [Algebraic] Active Concepts

- Event algebras: composite events
- Process algebras (e.g. CCS)
- consist of *composers/operators* to define composite events/processes,
- leaves of the terms are atomic domain-level events/actions,
- as operator trees: “standard” XML markup of terms
- RDF markup as languages,
- every expression can be associated with its language.

Composite Actions: Process Algebras

- e.g., CCS - Calculus of Communicating Systems [Milner‘80]
- operational semantics defined by transition rules, e.g.
  - a sequence of actions to be executed,
  - a process that includes “receiving” actions,
  - guarded (i.e., conditional) execution alternatives,
  - the start of a fixpoint (i.e., iteration or even infinite processes), and
  - a family of *communicating, concurrent processes*.
- Originally only over atomic processes/actions
- reading and writing simulated by communication a (send), $\overline{a}$ (receive) “match” as communication

... extend this to the (Semantic) Web environment with autonomous nodes.

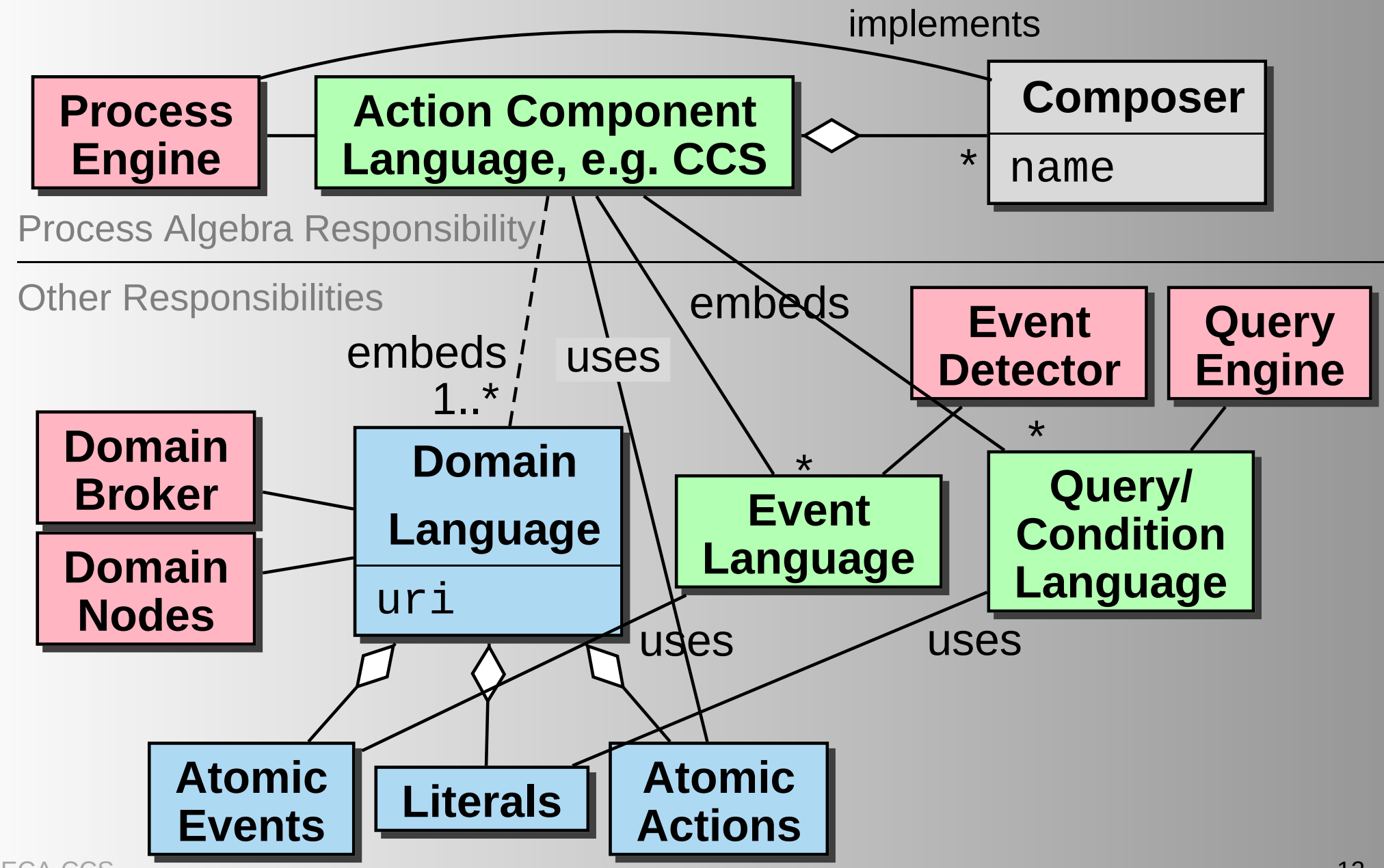
Adaptation of Process Algebras

Goal: specification of reactions in ECA rules

- liberal asynchronous variant of CCS: go on when possible, waiting and delaying possible
- extend with variable bindings semantics
- input variables come bound to values/URIs
- additional variables can be bound by “communication”
- queries as atomic actions: to be executed, contribute to the variable bindings
- event subexpressions as atomic actions: like waiting for $\overline{a}$ communication

$\Rightarrow$ subexpressions in other kinds of component languages

Languages in the Action Component



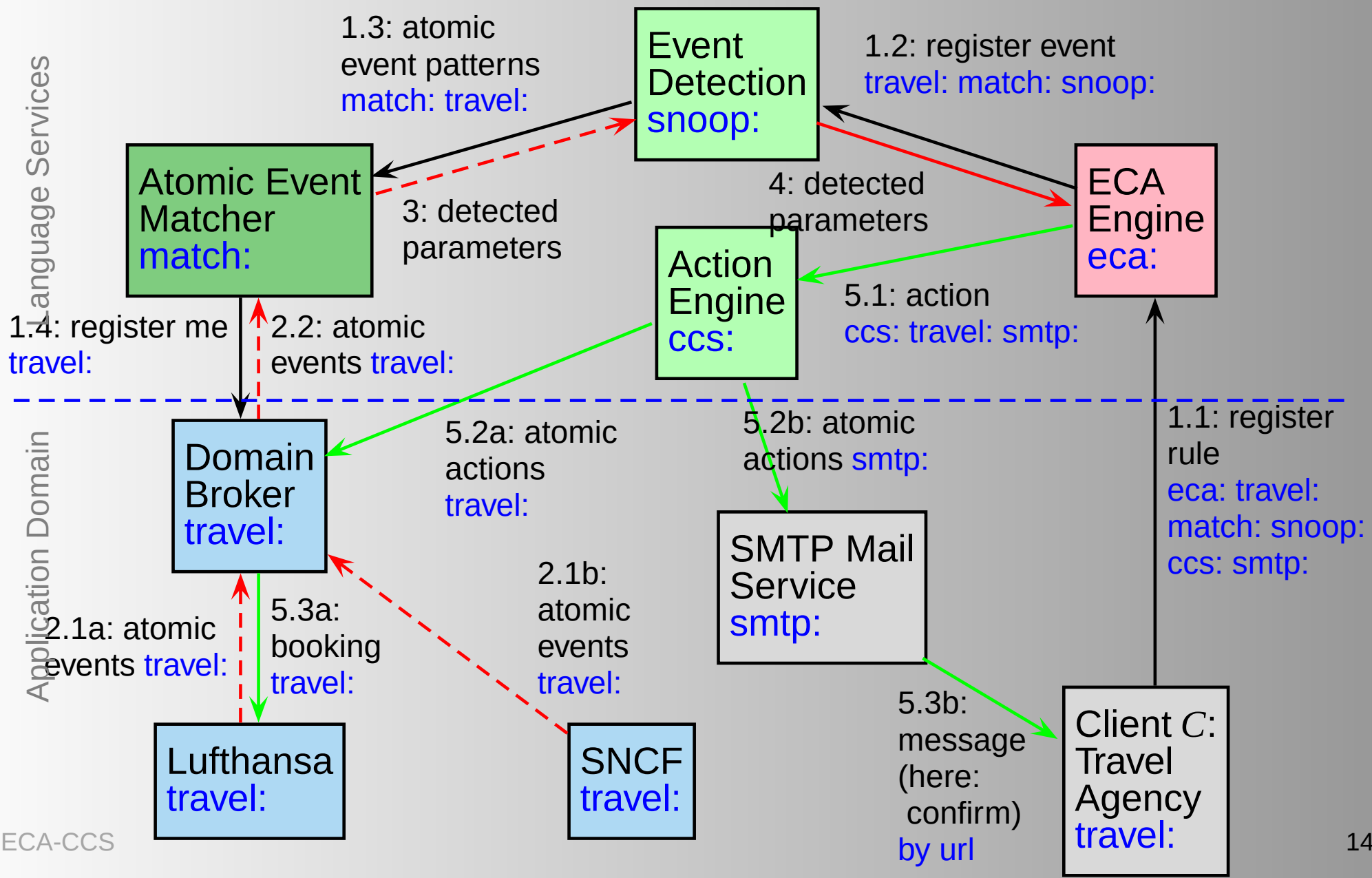
CCS Markup

- <ccs:sequence>*CCS subexpressions* </ccs:sequence>
  <ccs:alternative>*CCS subexpressions* </ccs:alternative>
  <ccs:concurrent>*CCS subexpressions* </ccs:concurrent>
- <ccs:fixpoint variables="X_1 X_2 . . . X_n" index="i" *// "my" index*
  localvars="..."> n subexpressions </ccs:fixpoint>
- <ccs:atomic-action>*domain-level action* </ccs:atomic-action>
  <ccs:event xmlns:*ev-ns*="uri">*event expression* </ccs:event>
  <ccs:query xmlns:*q-ns*="uri">*query expression* </ccs:query>
  <ccs:test xmlns:*t-ns*="uri">*test expression* </ccs:test>

Embedding Mechanisms: Same as in ECA-ML

- communication by logical variables
- namespaces for identifying languages of subexpressions

Service-Based Architecture



Comparison

- CCS (extended with events and queries) strictly more expressive than ECA rules alone:
  ECA pattern in CCS: $event$:$condition$:$action$,
- many ECA rules have much simpler actions and do not need CCS,
- useful to have CCS as an *option* for the action part.

Summary

- RDF/OWL as integrating semantic model in the Semantic Web
- describe events and actions of an application within its RDF/OWL model
- languages of different expressiveness/complexity available
- ECA rules
  - components
  - application-level atomic events and atomic actions
  - specific languages (event algebras, process algebras)
- Architecture: functionality provided by specialized nodes

Thank You
Questions ??

Further information and publications:
http://dbis.informatik.uni-goettingen.de/eca/

Complementing Slides

Action Component: Process Algebras

- example: CCS (Calculus of Communicating Systems, Milner 1980)
- describes the execution of processes as a transition system:
  (only the asynchronous transitions are listed)

$$a : P \xrightarrow{a} P \quad , \quad \frac{P_i \xrightarrow{a} P}{\sum_{i \in I} P_i \xrightarrow{a} P} \text{ (for } i \in I\text{)}$$

$$\frac{P \xrightarrow{a} P'}{P|Q \xrightarrow{a} P'|Q} \quad , \quad \frac{Q \xrightarrow{a} Q'}{P|Q \xrightarrow{a} P|Q'}$$

$$\frac{P_i\{\text{fix}\,\vec{X}\vec{P}/\vec{X}\} \xrightarrow{a} P'}{\text{fix}_i\vec{X}\vec{P} \xrightarrow{a} P'}$$

Atomic Event Specifications

Sample Event:

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

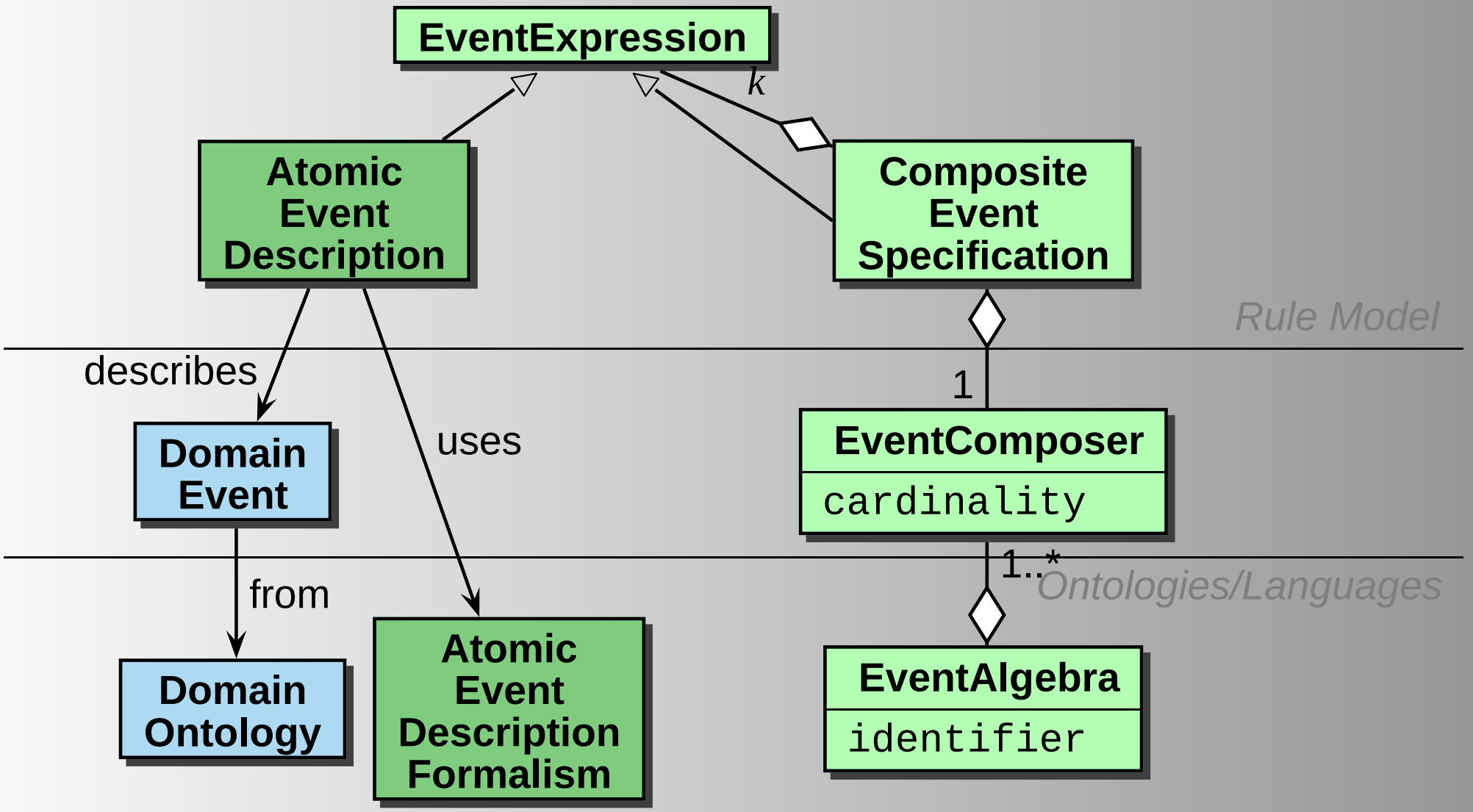
Event expressions require an auxiliary formalism for specifying relevant events:

- type of event ("travel:canceled-flight"),
- constraints ("must have a travel:reason subelement"),
- extract data from events ("bind @flight to variable flight")

Sample: XML-QL-style matching

```
<atomic-event language="match">
  <travel:canceled-flight flight="{$flight}"><travel:reason/></travel:canceled-flight>
</atomic-event>
```

Event Expressions: Languages



Sample Markup (Event Component)

```
<eca:rule xmlns:travel="...">
  <eca:variable name="theSeq">
    <eca:event xmlns:snoop="...">
    <snoop:sequence>
        <snoop:atomic-event language="match">
          <travel:delayed-flight flight="{$Flight}" minutes="{$Minutes}"/>
        </snoop:atomic-event>
        <snoop:atomic-event language="match">
          <travel:canceled-flight flight="{$Flight}"/>
        </snoop:atomic-event>
      </snoop:sequence>
    </eca:event>
  </eca:variable>
    :
</eca:rule>
```

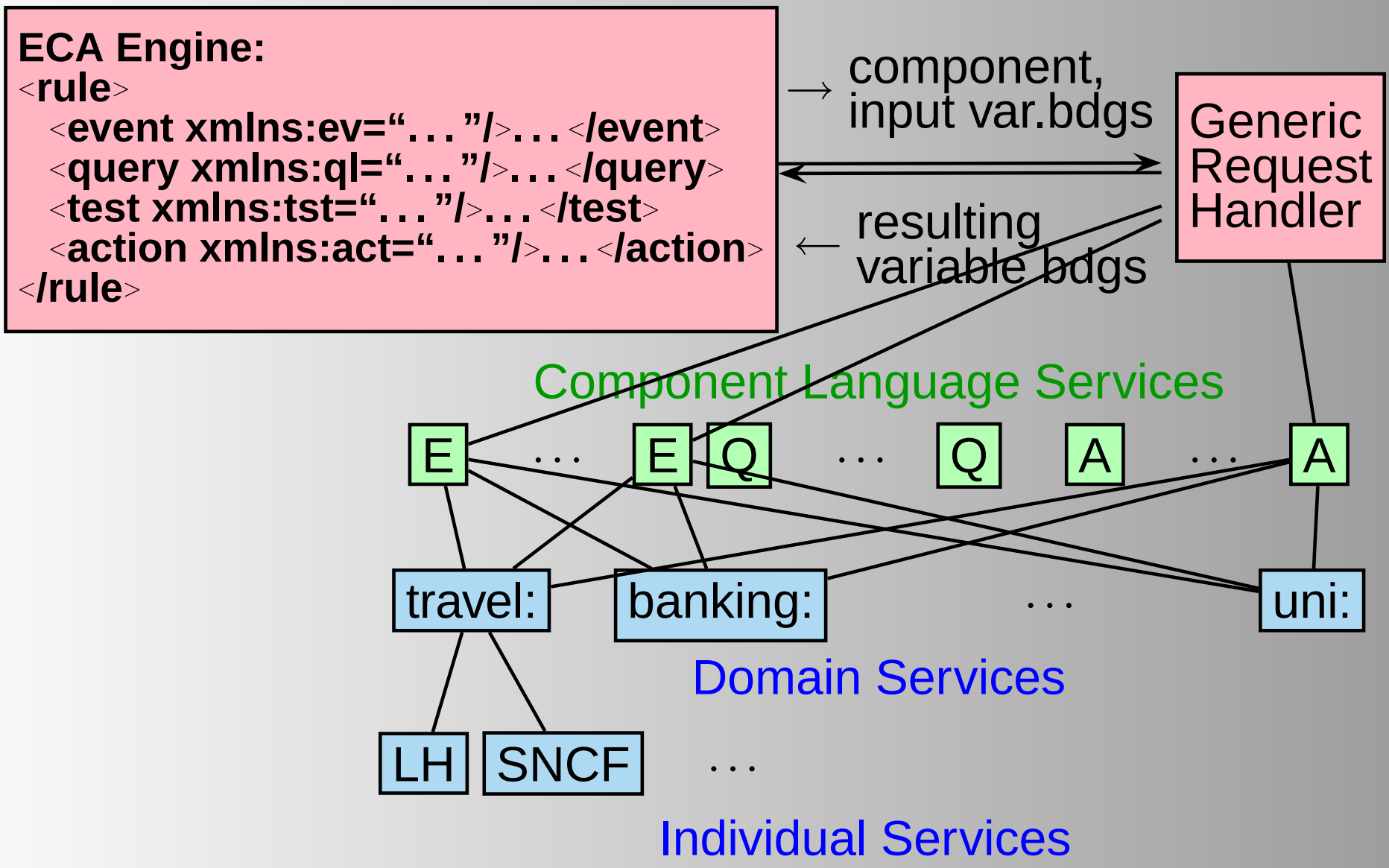
binds variables:

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

Tasks

- ECA Engine: Rule Semantics
  - Control flow: registering event component, receiving “firing” answer, continuing with queries etc.
  - Variable Bindings, Join Semantics
- Generic Request Handler: Mediator with Component Engines
  - depending on Service Descriptions
- Component Engines: dedicated to certain Event Algebras, Query Languages, Action Languages
- Domain Services (Portals): atomic events, queries, atomic actions

ECA Architecture



Communication of Variable Bindings

XML markup for communication of variable bindings:

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

Communication ECA → GRH

- the component to be processed
- bindings of all relevant variables

[Sample: a query component]

```
<eca:query xmlns:ql="url"
  rule="rule-id" component="component-id">
  <!-- query component -->
< eca:query>
<log:variable-bindings>
  <log:tuple> . . . </log:tuple>
      :
  <log:tuple> . . . </log:tuple>
<log:variable-bindings>
```

- *url* is the namespace used by the event language
- identifies appropriate service

Communication

ECA engine sends component to be processed together with bindings of all relevant variables to GRH.

Generic Request Handler (GRH)

- Submits component (with relevant input/used variable bindings) to appropriate service (determined by namespace/language used in the component)
- if necessary: does some wrapping tasks (for non-framework-aware services)
- receives results and transforms them into flat variable bindings and sends them back to the ECA engine ...
- ... where they are joined with the existing tuples ...
- ... and the next component is processed.

Communication Component Engine → GRH

- result-bindings-pairs (semantics of expression)

```
<log:answers rule="rule-id" component="component-id">
  <log:answer>
    <log:result>
      <!-- functional result -->
    </log:result>
    <log:variable-bindings>
      <log:tuple> ... </log:tuple>
          :
      <log:tuple> ... </log:tuple>
    </log:variable-bindings>
  </log:answer>
  <log:answer> ... </log:answer>
        :
  <log:answer> ... </log:answer>
</log:answers>
```

Communication GRH → ECA

- set of tuples of variable bindings
  (i.e., input/used variables and output/result variables)
- is then joined with tuples in ECA engine
- ... and next component is processed