Applying Complex Event Processing

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Agenda

- Brief introduction on CEP and Terminology
- Drools Vision
- Drools Fusion: Complex Event Processing extensions
  - Event Declaration and Semantics
  - Event Cloud, Streams and the Session Clock
  - Temporal Reasoning
  - Sliding Window Support
  - Streams Support
  - Memory Management
- Questions & Answers

Terminology: Event

"An event is an observable occurrence."

"An event in the Unified Modeling Language is a notable occurrence at a particular point in time."

http://www.wikipedia.org

"Anything that happens, or is contemplated as happening."

"An object that represents, encodes or records an event, generally for the purpose of computer processing"

http://complexevents.com

Terminology: Event

For the scope of this presentation:

"An event is a **significant change of state** at a particular **point in time**"

Terminology: Complex Event

"**Complex Event**, is an abstraction of other events called its members."

- Examples:
  - **The 1929 stock market crash** – an abstraction denoting many thousands of member events, including individual stock trades)
  - **The 2004 Indonesian Tsunami** – an abstraction of many natural events
  - **A completed stock purchase** -an abstraction of the events in a transaction to purchase the stock
  - **A successful on-line shopping cart checkout** – an abstraction of shopping cart events on an on-line website

- *Source: http://complexevents.com*

Terminology: CEP

"**Complex Event Processing**, or CEP, is primarily an event processing concept that deals with the task of processing multiple events with the goal of **identifying the meaningful events** within the event cloud.

CEP employs techniques such as **detection** of complex patterns of many events, event **correlation** and **abstraction**, event hierarchies, and relationships between events such as causality, membership, and timing, and event-driven processes."

-- wikipedia

Terminology: CEP

- Examples:
  - The Drools Bootcamp impact:
    - *The Eyjafjallajokull glacier volcano eruption in Iceland*
    - *Followed by the ash cloud drifting southeast over Europe*
    - *Causing air traffic disruption in over 20 European and Asian countries*
    - *Affecting plans of the Drools Bootcamp in San Diego, CA*
  - Paul's pickpocket event on Rome's subway
  - Credit card fraud detection
  - Logistics Real-Time Awareness solution
  - Neonatal ICU: infant vital signs monitoring

Terminology: CEP vs ESP

Complex Event Processing, or CEP, and **Event Stream Processing**, or ESP, are two technologies that were born separate, but converged.

- An *oversimplification*: In their origins...
  - Event Stream Processing focused on the ability to process high volume **streams** of events.
  - Complex Event Processing focused on defining, detecting and processing the **relationships** among events.

Terminology: CEP and ESP

For the scope of this presentation:

"CEP is used as a common term meaning both CEP and ESP."

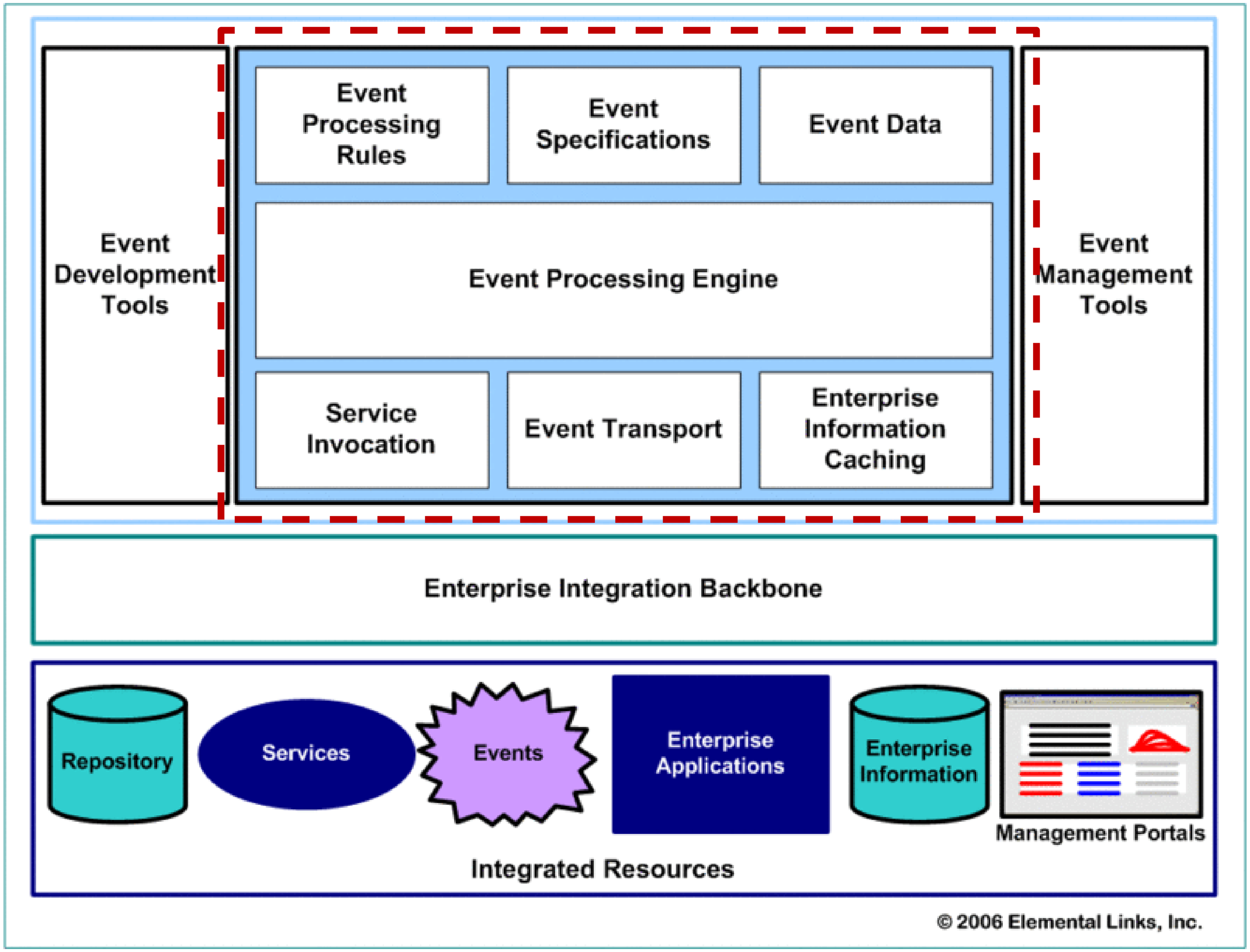
Terminology: EDA

"**Event Driven Architecture (EDA)** is a software architecture pattern promoting the production, detection, consumption of, and reaction to events. An event can be defined as "a significant change in state"[1]. For example, when a consumer purchases a car, the car's state changes from "for sale" to "sold". A car dealer's system architecture may treat this state change as an event to be produced, published, detected and consumed by various applications within the architecture."

http://en.wikipedia.org/wiki/Event_Driven_Architecture

EDA vs CEP

CEP is a **component** of the EDA

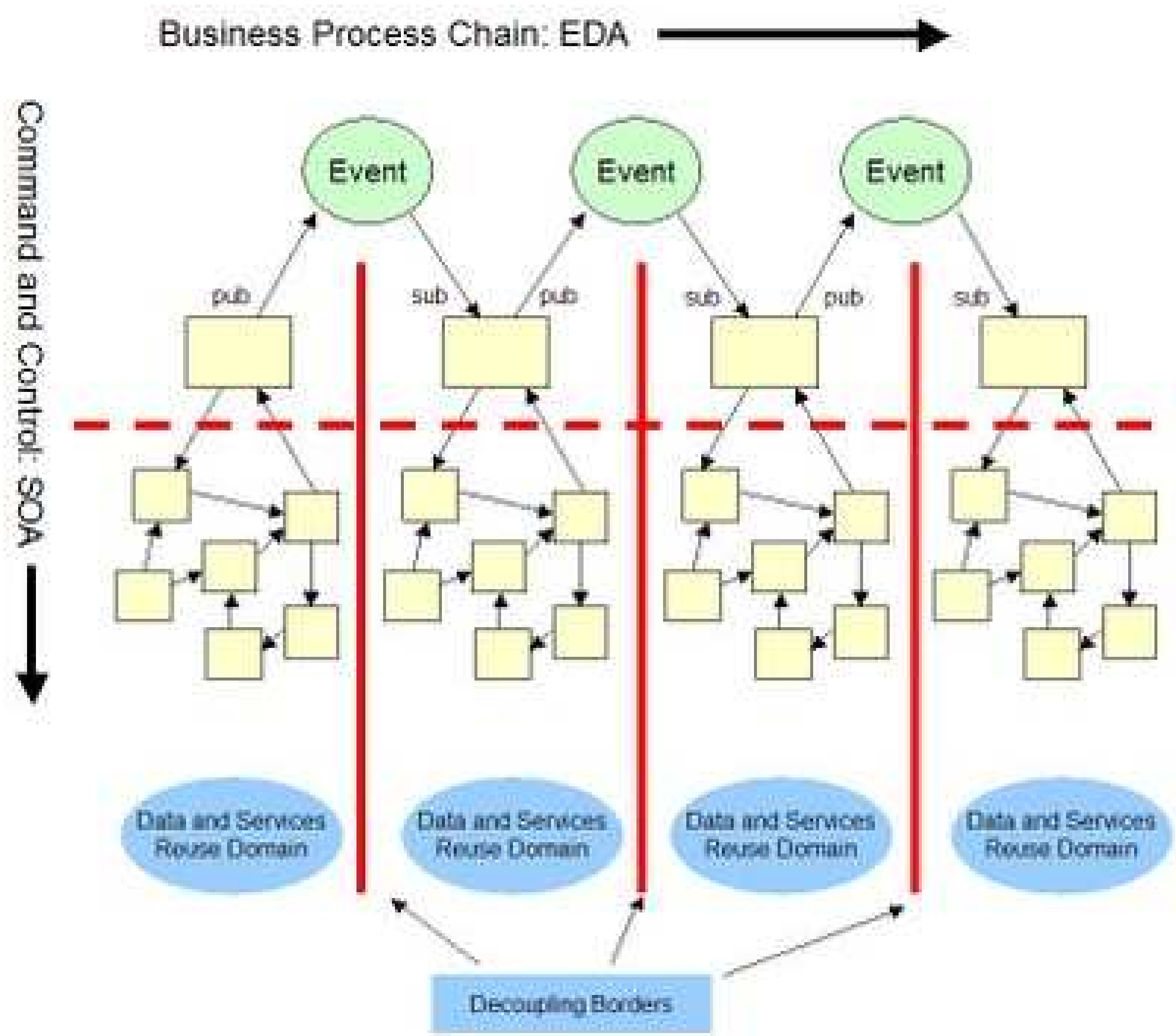


Source: http://elementallinks.typepad.com/.shared/image.html?/photos/uncategorized/simple_event_flow.gif

EDA vs SOA

- EDA is ****not**** SOA 2.0
- Complementary architectures
- Metaphor
  - In our body:
    - SOA is used to build our muscles and organs
    - EDA is used to build our sensory system

EDA vs SOA



Source: http://soa-eda.blogspot.com/2006/11/how-eda-extends-soa-and-why-it-is.html

Complex Event Processing

- **A few characteristics of common CEP scenarios:**
  - Huge volume of events, but only a few of real interest
  - Usually events are immutable
  - Usually queries/rules have to run in reactive mode
  - Strong temporal relationships between events
  - Individual events are usually not important
  - The composition and aggregation of events is important

Drools Vision

Guvnor

Expert

Fusion

Flow

“A common platform to model and govern the business logic of the enterprise.”

Motivation

- Business Rules, Event Processing and Business Processes are all modelled declaratively.
- A business solution usually involves the interaction between these technologies.
- In short:
  - Technology overlap
  - Business overlap
- Several (good) products on the market:
  - Better either at CEP/ESP or Rules Processing or Business Processes
- The approach: attribute the same importance to the three complementary business modeling techniques

JBoss Enterprise BRMS Platform v5*

JBoss Enterprise SOA Platform v5*

* Tech preview

Drools Fusion: Enables…

- **Event Detection:**
  - From an event cloud or set of streams, select all the meaningful events, and only them.
- **[Temporal] Event Correlation:**
  - Ability to correlate events and facts declaring both temporal and non-temporal constraints between them.
  - Ability to reason over event aggregation
- **Event Abstraction:**
  - Ability to compose complex events from atomic events AND reason over them

Drools Fusion

- **Features:**
  - Event Semantics as First Class Citizens
  - Allow Detection, Correlation and Composition
  - Temporal Constraints
  - Session Clock
  - Stream Processing
  - Sliding Windows
  - CEP volumes (scalability)
  - (Re)Active Rules
  - Data Loaders for Input

Event Declaration and Semantics

```
// declaring existing class
import some.package.VoiceCall
declare VoiceCall
  @role( event )
  @timestamp( calltime )
  @duration( duration )
end

// generating an event class
declare StockTick
  @role( event )

  symbol : String
  price : double
end
```

- Event semantics:
  - Point-in-time and Interval
- An event is a fact with a few special characteristics:
  - Usually immutable, but not enforced
  - Strong temporal relationships
  - Lifecycle may be managed
  - Allow use of sliding windows
- "All events are facts, but not all facts are events."

Temporal Reasoning

- Semantics for:
  - **time:** discrete
  - **events:** point-in-time and interval
- Ability to express temporal relationships:
  - Allen's 13 temporal operators

- **James F. Allen** defined the 13 possible temporal relations between two events.
- **Eiko Yoneki** and **Jean Bacon** defined a unified semantics for event correlation over time and space.

Temporal Relationships

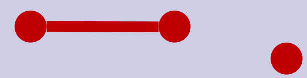
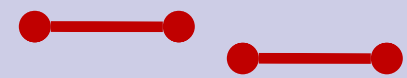
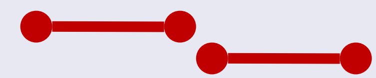
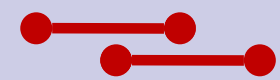
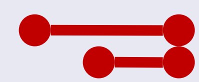
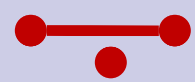
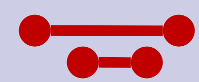
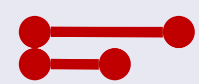
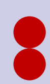
```
rule “Shipment not picked up in time”
when
    Shipment( $pickupTime : scheduledPickupTime )
    not ShipmentPickup( this before $pickupTime )
then
    // shipment not picked up... action required.
end
```

Temporal Relationships

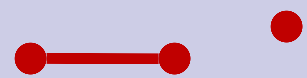
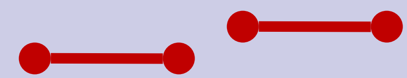
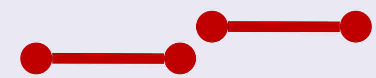
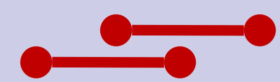
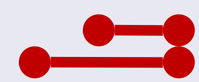
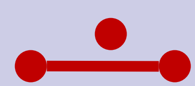
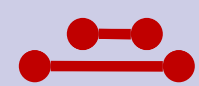
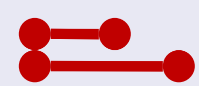
```
rule "Shipment not picked up in time"
when
    Shipment( $pickupTime : scheduledPickupTime )
    not ShipmentPickup( this before $pickupTime )
then
    // shipment not picked up... Action required.
end
```

Temporal Relationship

Allen’s 13 Temporal Operators

		Point-Point	Point-Interval	Interval-Interval
A before B	A B			
A meets B	A B			
A overlaps B	A B			
A finishes B	A B			
A includes B	A B			
A starts B	A B			
A coincides B	A B			

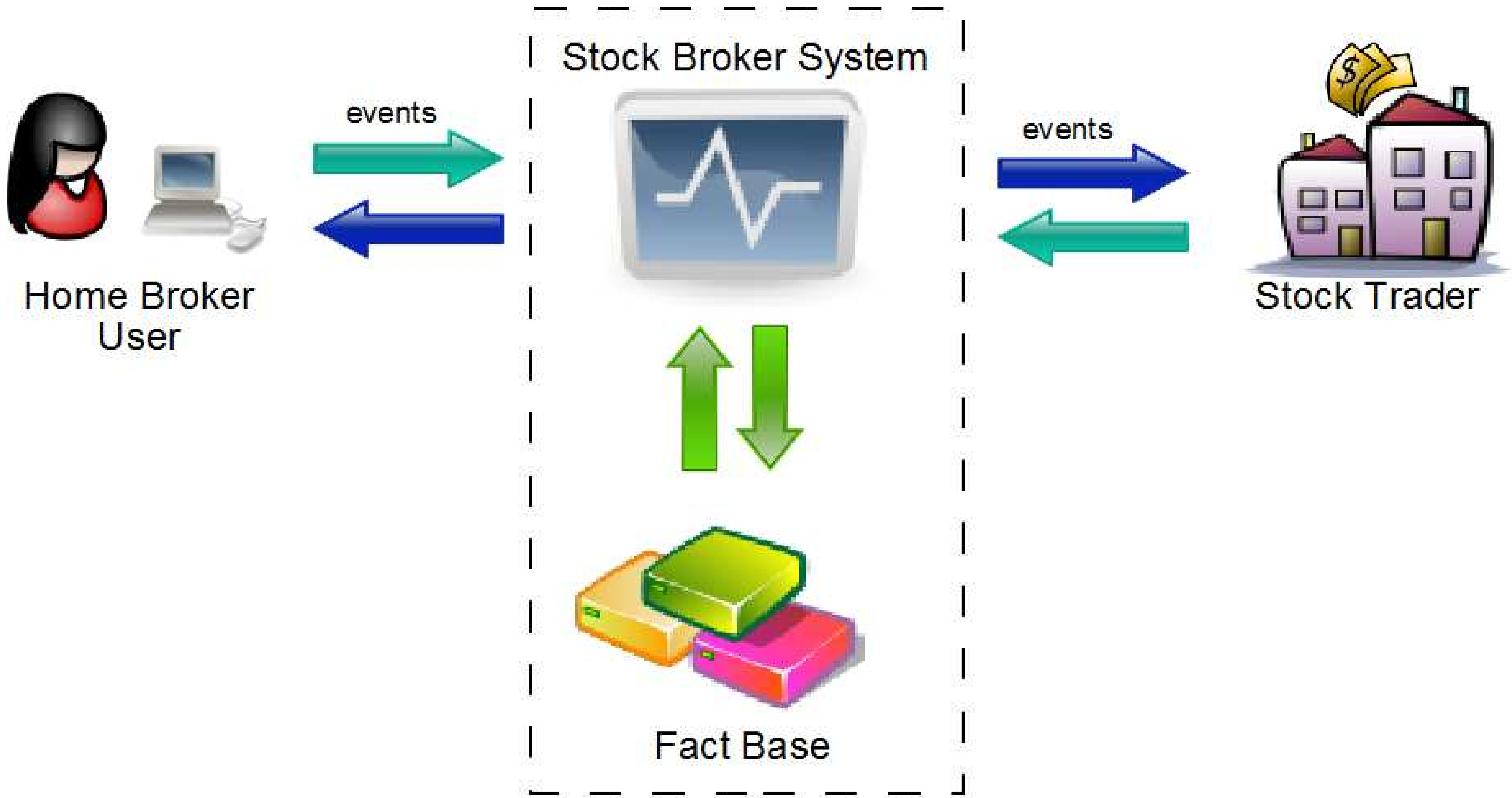
Allen's 13 Temporal Operators

	Point-Point	Point-Interval	Interval-Interval
A after B			
A metBy B			
A overlapedBy B			
A finishedBy B			
A during B			
A finishes B			

Some references

- **Allen, J. F**. *An interval-based representation of temporal knowledge*. 1981.
- **Allen, J. F**. *Maintaining knowledge about temporal intervals*. 1983
- **Yoneki, Eiko and Bacon, Jean**. *Unified Semantics for Event Correlation Over Time and Space in Hybrid Network Environments*. 2005.
- **Bennett, Brandon and Galton, Antony P**. *A Unifying Semantics for Time and Events*. 2000.

Simple Example Scenario



Stream Support (entry-points)

- **A scoping abstraction for stream support**
  - Rule compiler gather all entry-point declarations and expose them through the session API
  - Engine manages all the scoping and synchronization behind the scenes.

stock.drl

```
package com.sample

rule "Stock Trade Correlation"
when
    $c: Customer( type == "VIP" )
    BuyOrderEvent( customer == $c, $id : id ) from entry-point "Home Broker Stream"
    BuyAckEvent( relatedEvent == $id ) from entry-point "Stock Trader Stream"
then
    // take some action
end
```

Text Editor | Rete Tree

```
StatefulSession session = …
EntryPoint ep = session.getEntryPoint(“Home Broker Stream”);
…
ep.insert(…);
ep.insert(…);
…
```

Cloud Mode, Stream Mode, Session Clock

CLOUD	STREAM

CLOUD

- No notion of "flow of time": the engine sees all facts without regard to time
- No attached Session Clock
- No requirements on event ordering
- No automatic event lifecycle management
- No sliding window support

STREAM

- Notion of "flow of time": concept of "now"
- Session Clock has an active role synchronizing the reasoning
- Event Streams must be ordered
- Automatic event lifecycle management
- Sliding window support
- Automatic rule delaying on absence of facts

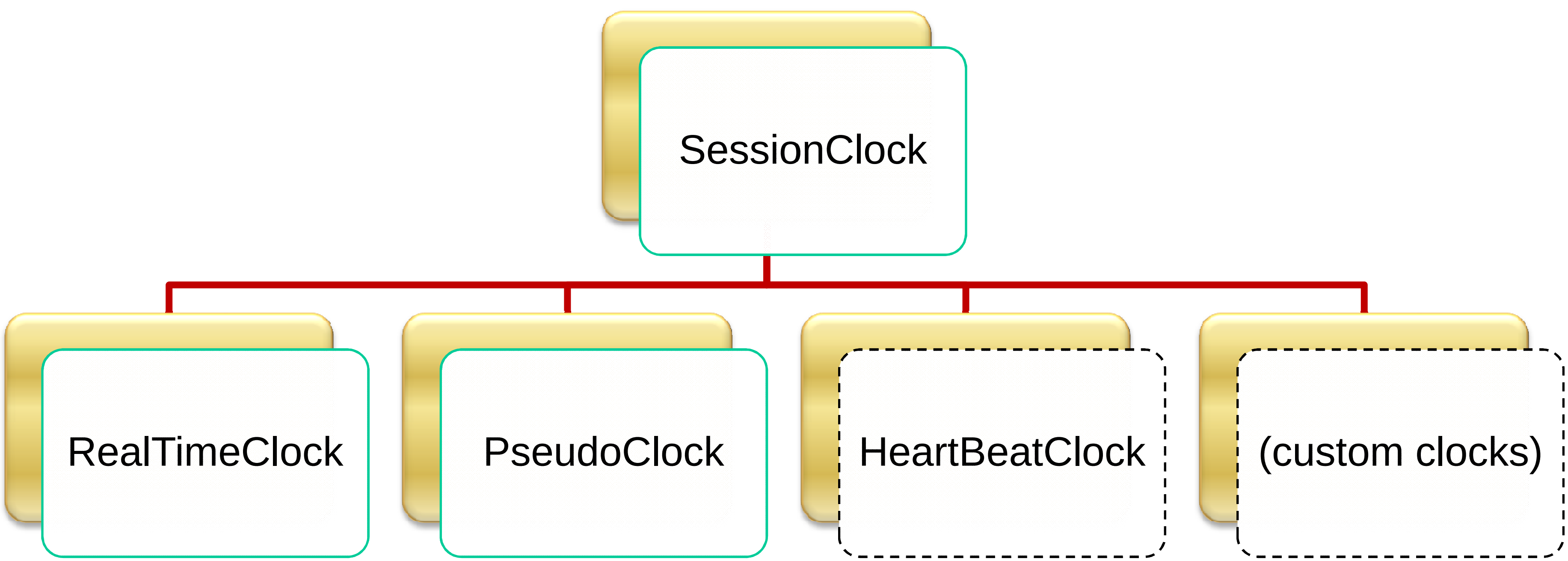
Reference Clock

- Reference clock defines the flow of time

- Named **Session Clock**
  - is assigned to each session created
- Synchronizes time sensitive operations
  - duration rules
  - event streams
  - process timers
  - sliding windows

Session Clock

- Uses the strategy pattern and multiple implementations:
  - Real-time operation
  - Tests
  - Simulations
  - etc



Session Clock

- Selecting the session clock:
  - API:

```
KnowledgeSessionConfiguration conf = ...
conf.setOption( ClockTypeOption.get( “realtime” ) );
```

  - System Property or Configuration File:

```
drools.clockType = pseudo
```

Sliding Window Support

- Allows reasoning over a moving window of “interest”
  - Time
  - Length

```
rule “Average Order Value over 12 hours”
when
    $c : Customer()
    $a : Number() from accumulate (
            BuyOrder( customer == $c, $p : price ) over window:time( 12h ),
            average( $p ) )
then
    // do something
end
```

Delaying Rules

- Negative patterns may require rule firings to be delayed.

```
rule “Order timeout”
when
    $bse : BuyShares ( $id : id )
    not BuySharesAck( id == $id, this after[0s,30s] $bse )
then
    // Buy order was not acknowledged. Cancel operation
    // by timeout.
end
```

Delaying Rules

- Negative patterns may require rule firings to be delayed.

```
rule "Order timeout"
when
   $bse : BuyShares ( $id : id )
   not BuySharesAck( id == $id, this after[0s,30s] $bse )
then
   // Buy order was not acknowledged. Cancel operation
   // by timeout.
end
```

Forces the rule to wait for 30 seconds before firing, because the acknowledgement may arrive at any time!

Some references

- **Ghanem, Hammad, Mokbel, Aref and Elmagarmid**. *Incremental Evaluation of Sliding-Window Queries over Data Streams*.

Temporal Dimension

- Requires the support to the temporal dimension
  - A rule/query might match in a given point in time, and not match in the subsequent point in time

- That is the single most difficult requirement to support in a way that the engine:
  - stays deterministic
  - stays a high-performance engine
- Achieved mostly by compile time optimizations that enable:
  - constraint tightening
  - match space narrowing
  - memory management

Temporal Dimension Support

- CEP scenarios are stateful by nature.
- Events usually are only interesting during a short period of time.
- Hard for applications to know when events are not necessary anymore
    - Temporal constraints and sliding windows describe such "window of interest"

Simple Example Rule

```
rule "Bag was not lost"
when
    $c : BagEvent(  ) from entry-point "check-in"
    $l : BagEvent( this == $c.bagId, this after[0,5m] $c )
                               from entry-point "pre-load"
then
    // bag was not lost
end
```

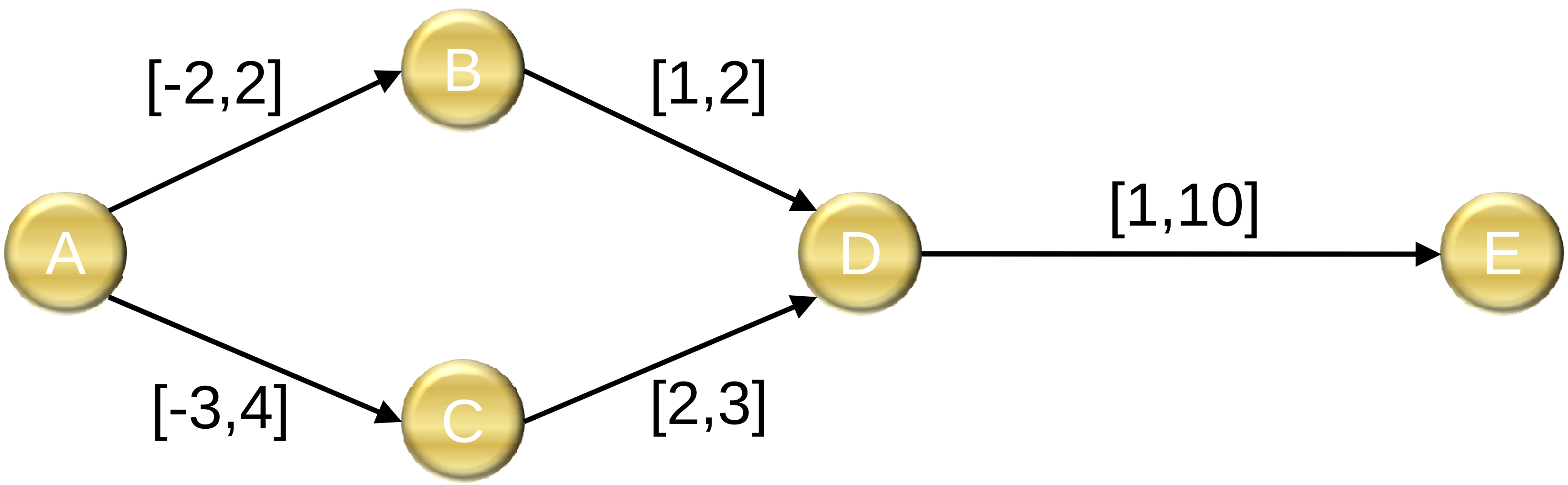
Abstract Example Rule

```
rule "reasoning on events over time"
when
    $a : A( )
    $b : B( this after[-2,2] $a )
    $c : C( this after[-3,4] $a )
    $d : D( this after[1,2] $b, this after[2,3] $c )
    not E( this after[1,10] $d )
then
    // do something
end
```

Temporal Distance Algorithm

1. Gather all temporal relationships between events
2. Create the temporal dependency graph as a dependency matrix
3. Calculate the reflexive and transitive closures
   - Floyd-Warshall algorithm: $O(n^3)$
4. Check for unbound intervals
   - Infinite time-windows
5. Calculate the maximum expiration time for each of the event types
6. Calculate necessary delay for the rules with negative patterns

Temporal Dependency Matrix



	A	B	C	D	E
A	[0, 0]	[-2, 2]	[-3, 4]	[-∞, ∞]	[-∞, ∞]
B	[-2, 2]	[0, 0]	[-∞, ∞]	[1, 2]	[-∞, ∞]
C	[-4, 3]	[-∞, ∞]	[0, 0]	[2, 3]	[-∞, ∞]
D	[-∞, ∞]	[-2, -1]	[-3, -2]	[0, 0]	[1, 10]
E	[-∞, ∞]	[-∞, ∞]	[-∞, ∞]	[-10, -1]	[0, 0]

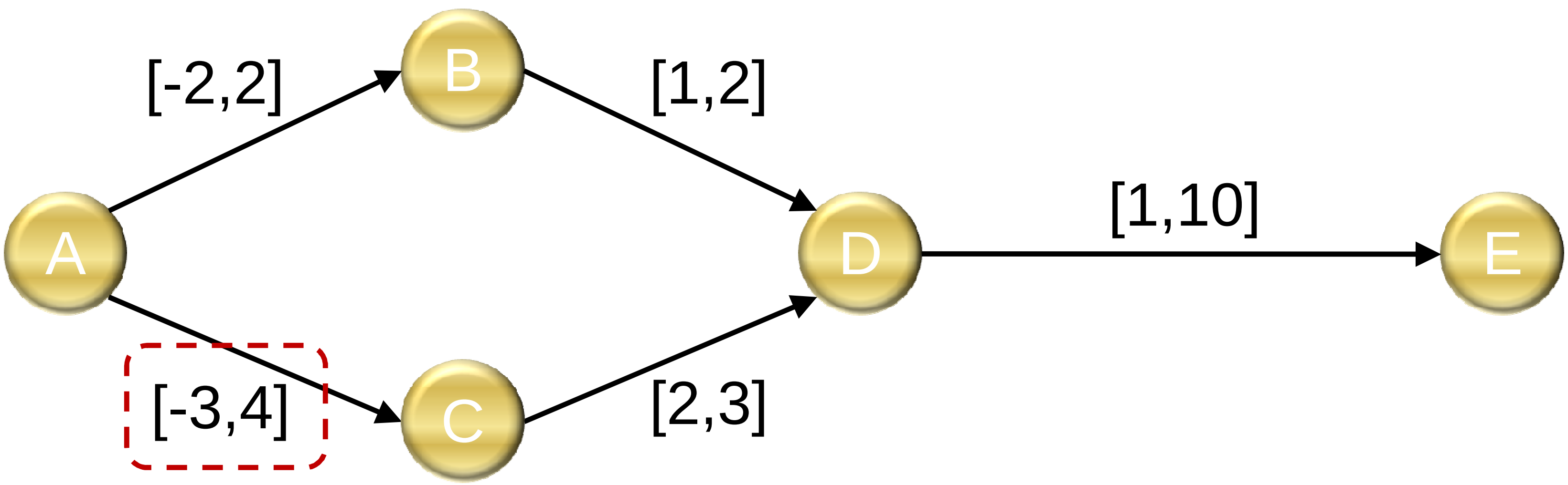
Temporal Dependency Matrix

	A	B	C	D	E
A	[0, 0]	[-2, 2]	[-3, 4]	[-∞, ∞]	[-∞, ∞]
B	[-2, 2]	[0, 0]	[-∞, ∞]	[1, 2]	[-∞, ∞]
C	[-4, 3]	[-∞, ∞]	[0, 0]	[2, 3]	[-∞, ∞]
D	[-∞, ∞]	[-2, -1]	[-3, -2]	[0, 0]	[1, 10]
E	[-∞, ∞]	[-∞, ∞]	[-∞, ∞]	[-10, -1]	[0, 0]

Transitive Closure

	A	B	C	D	E
A	[0, 0]	[-2, 2]	[-3, 2]	[-1, 4]	[0, 14]
B	[-2, 2]	[0, 0]	[-2, 0]	[1, 2]	[2, 12]
C	[-2, 3]	[0, 2]	[0, 0]	[2, 3]	[3, 13]
D	[-4, 1]	[-2, -1]	[-3, -2]	[0, 0]	[1, 10]
E	[-14, 0]	[-12, -2]	[-13, -3]	[-10,-1]	[0, 0]

Temporal Dependency Matrix



	A	B	C	D	E
A	[0, 0]	[-2, 2]	[-3, 2]	[-1, 4]	[0, 14]
B	[-2, 2]	[0, 0]	[-2, 0]	[1, 2]	[2, 12]
C	[-2, 3]	[0, 2]	[0, 0]	[2, 3]	[3, 13]
D	[-4, 1]	[-2, -1]	[-3, -2]	[0, 0]	[1, 10]
E	[-14, 0]	[-12, -2]	[-13, -3]	[-10,-1]	[0, 0]

Some references

- **Teodosiu, Dan and Pollak, Günter**. *Discarding Unused Temporal Information in a Production System*.

Q&A

- **Drools project site:**
  - http://www.drools.org (http://www.jboss.org/drools/)
- **Documentation:**
  - http://www.jboss.org/drools/documentation.html

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