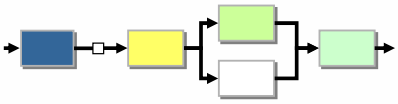
SOACON 2007
Where IT Aligns With Business

Gregor Hohpe | Google

Programming Without a Call Stack: Event-driven Architectures

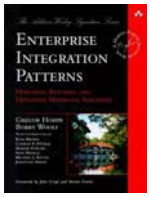


www.eaipatterns.com

Who's Gregor?

- **Distributed systems, enterprise integration, service-oriented architectures**
- **MQ, MSMQ, JMS, TIBCO, BizTalk, Web Services**
- **Write code every day. Share knowledge through patterns.**

eaipatterns.com
- Patterns
- Articles
- Blog



Enterprise Integration Patterns
Addison-Wesley

Integration Patterns
Microsoft Press

Enterprise Solution Patterns
Microsoft Press

Best Software Writing I
APress

SOA Experten-wissen
dpunkt Verlag

1

Agenda

- It's All About Coupling
- Events Everywhere
- Event-driven Architectures
- Developing in an EDA
- Case Study: Building an EDA in Java™

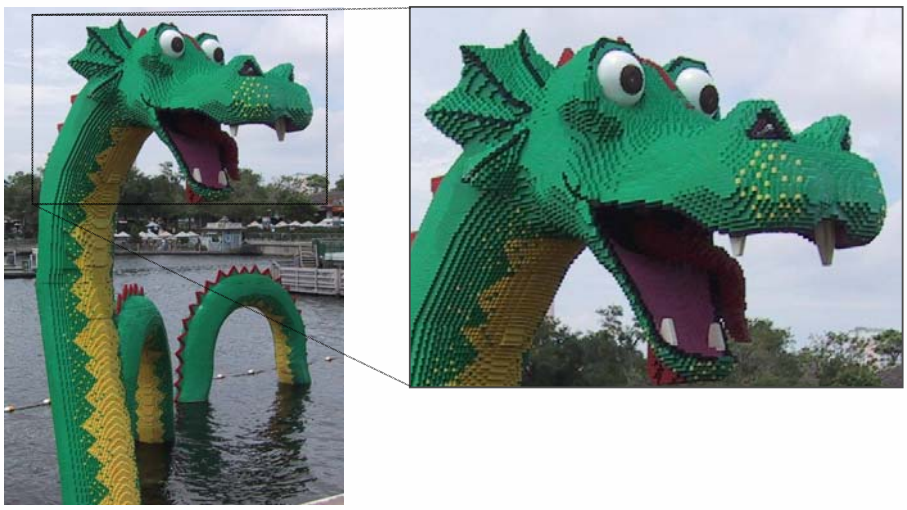
2

In A Connected World It's All About Coupling

"Measure of dependency between components"

3

Dynamic Composability



"The ability to build new things from existing pieces."

4

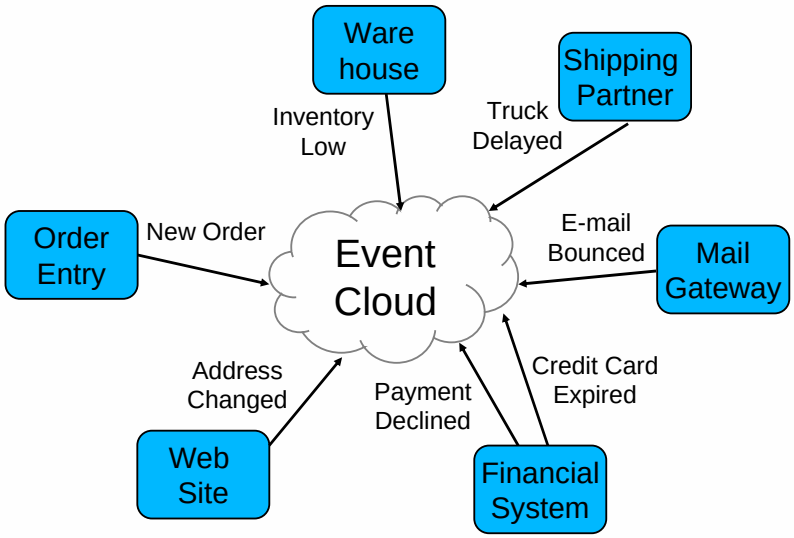
Interaction Takes Center Stage

"The lines are becoming boxes now."

-- Ralf Westphal

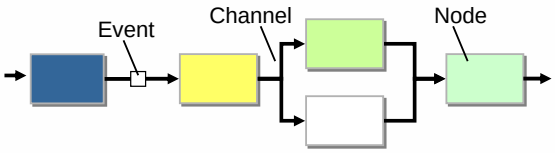
5

The World is Full of Events



6

Event-Driven Architecture (EDA)

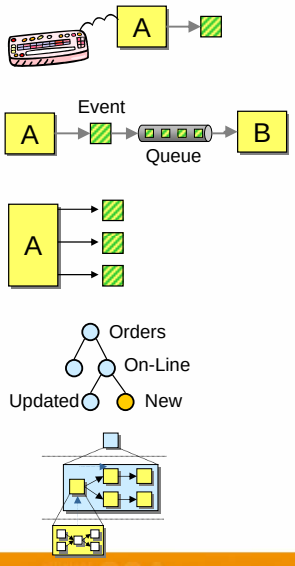


- **Distributed processing, no central control.**
- **Nodes respond to incoming events and publish events in response.**
- **Event channels transport events from one node to the next, usually asynchronously (sender does not wait).**
- **Composition through channels.**

7

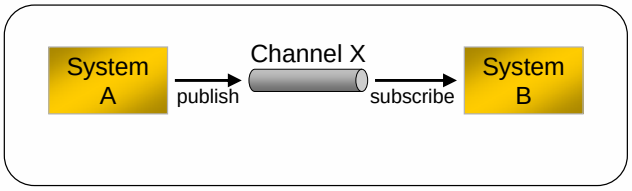
EDA Defining Qualities

- **Timeliness**. Publish events as they occur instead of waiting for the next batch cycle.
- **Asynchrony**. The publishing system does not wait for the receiving system(s) to process the event.
- **Fine Grained**. Publish single events as opposed to large aggregated event.
- **Ontology**. A nomenclature to classify and express interest in certain groups of events.
- **Complex Event Processing**. Understanding the relationships between events, for example aggregation and causality.



8

Composition via Channels

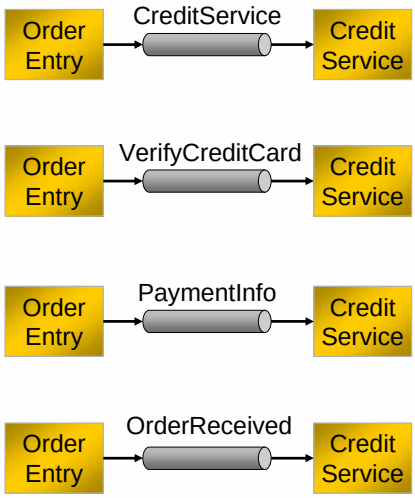


- **Nodes communicate via Channels**
- **Sender and receiver need to agree to a common channel. This is a form of coupling.**
- **Sender and receiver have to decide which channel is "right". The burden can be shifted between sender and receiver.**
- **Channel namespace provides some structure.**

9

Channel Naming and Semantics

- **Target component**
- **Action / Operation**
- **Document**
- **Event**



10

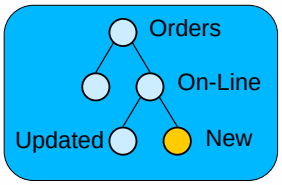
How Do A and B Connect?

Structured

- **Channel Name / Instance**
  - **Common in message queue systems.**
  - **Limited expressiveness.**

```
MessageQueue q = new
MessageQueue("foo");

q.Send("Msg");
```

- **Topic Hierarchy**
  - **Allows wildcard subscription**
  - **Requires mapping of topic space onto a tree. Forces prioritization.**



- **Content-based**
  - **Flexible, but difficult to implement efficiently in widely distributed systems.**

```
Channel.Subscribe(
"/element/foo='bar'"
);
```

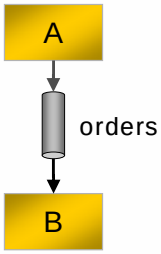
Unstructured

11

Composition Strategies

- **Implicit Composition**

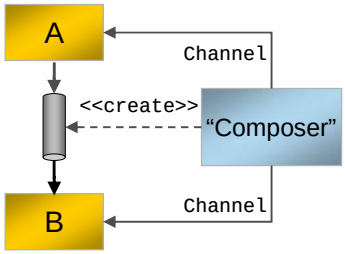
```
channel = Channel.byName("orders");
channel.publish(message);
```




```
channel = Channel.byName("orders");
channel.subscribe(eventHandler);
```

- **Explicit Composition**

```
A(Channel ch) { this.channel = ch; }
…
channel.publish(message);
```



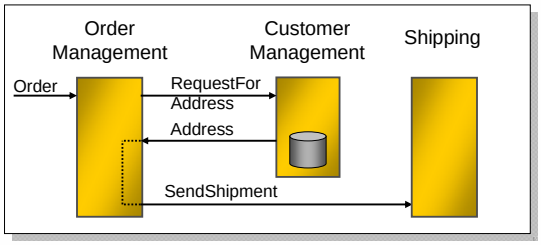

```
B(Channel ch) { this.channel = ch; }
…
channel.subscribe(eventHandler);
```

12

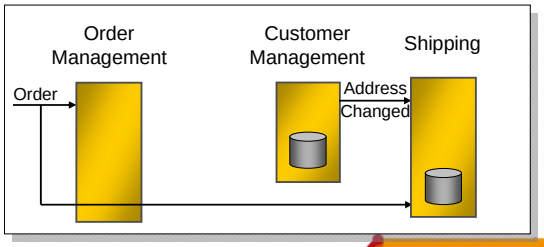
Event Collaboration

Multiple Components work together by communicating with each other by sending events when their internal state changes. (Fowler)

Request Collaboration



Event Collaboration



13

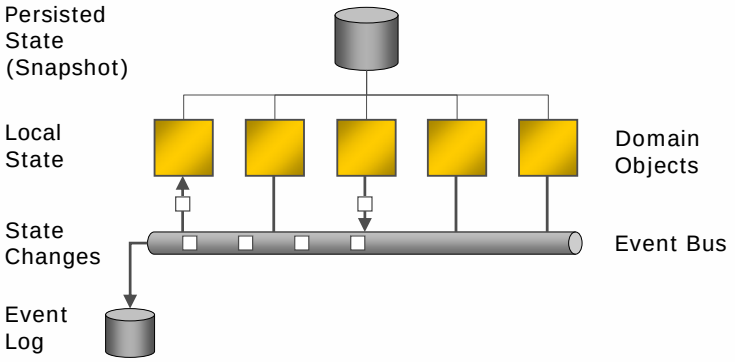
Event Collaboration

- **Adding Consumers is Side-Effect Free**
  - **Debugging / logging / sniffing**
  - **Parallel implementations**
- **Simple components, more complex interactions**
- **Robust against unstable connections**
- **Can be difficult to manage and /or debug**
  - **Need to understand relationship between events**
  - **Shift burden from design-time to run-time**
- **Components may operate on stale data**

14

Event-sourced Systems

Capture all changes to an application state as a sequence of events. (Fowler)



15

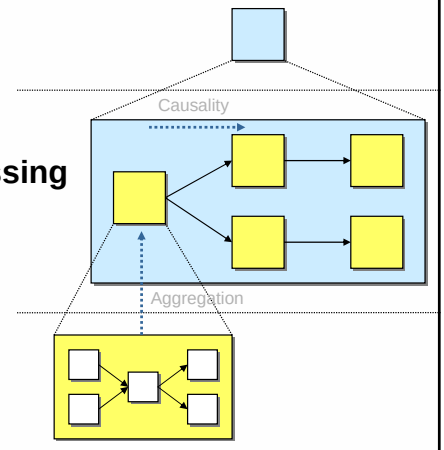
Event-sourced Systems

- **More than an event log or "temporal database"**
- **Rebuild state based on events by re-executing behavior**
- **Temporal Query**
  - **Determine application state at specific point in time**
- **Event replay**
  - **Run "what if" scenarios or corrections to past events**
- **Limitation: code changes**

16

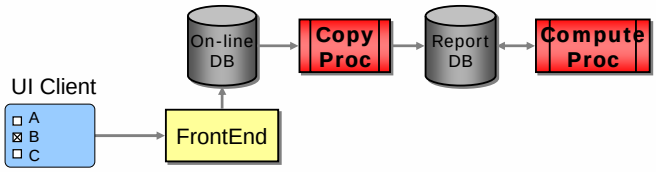
Composite Events Processing

- **Understand causality**
- **Some events are the result a of a sequence of events**
- **CEP = Complex Event Processing**
- **Pattern matching languages can be challenging**



17

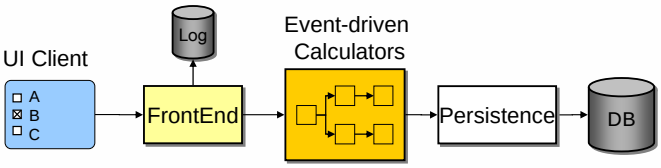
Case Study – Existing System



- **Compute statistics based on responses to on-line questionnaires**
- **Responses stored in database**
- **At the end, stored procedure computes "scores" based on user responses**
  - **Load on RDBMS**
  - **Single thread, monolithic, synchronous**
  - **Poor response time at end of user session**
- **Goal: scalable, extensible architecture**

18

Case Study – New Architecture



- **Decompose logic into individual "calculators"**
- **Calculators precompute results as response events arrive**
- **Channels connect calculators**
- **Calculators do not updates database**
- **Persist results into database once all scores computed**
- **Pure Java (1.4) implementation**

19

Design Decisions

- Point-to-Point vs. Publish-Subscribe Channels
- Distributed vs. Distributable
- Asynchronous vs. One-Way
- Technology Specific vs. Technology Neutral
- Explicit vs. Implicit Composition
- Channel Naming "ontology"
  - String match
  - Hierarchy (Class Hierarchy)
  - Content-based
- Automated Dispatch vs. Manual Dispatch

20

Implementation

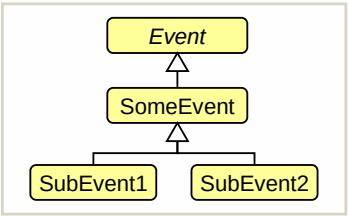
```
public interface Channel {

  public void send(Event event);

  public void subscribe(EventRecipient recipient,
                        Class eventClass);
}
```

Marker Interface

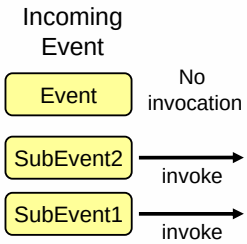
- Multiple calculators subscribe to abstract Channel
- Channel stores subscribers by event type (hierarchy)
- For each incoming event, channel looks up all subscribers for the event type and its superclasses
- For each subscribing class, figure out the overriding onEvent method with the most specific matching argument

21

Subscription / Dispatching



Event Hierarchy




```
Class SomeEvent extends Event {}
class SubEvent1 extends SomeEvent {}
class SubEvent2 extends SomeEvent {}

class SomeSubscriber {
  public SomeSubscriber {
    channel.subscribe(SomeEvent.class);
  }

  public void onEvent (Event e) {}

  public void onEvent (SubEvent1 se) {}
}
```

22

Channel Implementation

```
public void send(Event event) {
  Set<EventRecipient> subscribers =
      getSubscribersForEventTypeAndItsSuperTypes(event.getClass());
  for (EventRecipient recipient : subscribers) {
    EventProcessorHelper.invokeEventHandler(event, recipient);
  }
}
```

```
Map<Class, Set<EventRecipient>> subs;

Set<EventRecipient> getSubscribersForEventTypeAndItsSuperTypes
    (Class eventClass) {
  Set<EventRecipient> allSubscribers = new HashSet<EventRecipient>();

  for (Map.Entry<Class, Set<EventRecipient>> entry : subs.entrySet()) {
    Class subscriberEventClass = entry.getKey();
    if (subscriberEventClass.isAssignableFrom(eventClass)) {
      allSubscribers.addAll(entry.getValue());
    }
  }
  return allSubscribers;
}
```

23

Channel Implementation (Cont'd)

```
boolean invokeEventHandler(Event event, EventRecipient recip)
{
  for (Class eventClass = event.getClass();
       eventClass != null;
       eventClass = eventClass.getSuperclass()) {
    Method eventHandler = recip.getClass().getMethod
           ("onEvent", new Class[]{eventClass});
    try {
      eventHandler.invoke(recip, new Object[] {event});
      return true;
    } catch (…) {…}

    if (Event.class.equals(eventClass))
      return false;
  }
  return false;
}
```

24

Channel Behaviors

```
public void testEachSubscriberReceivesMessage() {…}
public void testSubscribeTwiceReceiveOnce() {…}
public void testBaseClassSubscriberReceivesDerivedClassEvents() {…}
public void testSubscribingForNonEventTypeThrows() {…}

public void testInvokesExactlyMatchingMethodForBaseEventType() {…}
public void testInvokesExactlyMatchingMethodForEventSubType() {…}
public void testDoesNothingForOverlySpecificEventHandler() {…}
public void testInvokesMostSpecificMethodIfBothAreAvailable() {…}
```

25

Cool Things

- **Testing components in isolation**
- **Publish-subscribe enables adding rather than replacing**
- **Replay of events to recover transient state**
- **Tracing / logging trivial, almost aspect-like**

```
public class DebugCalculator extends Calculator
{
  public DebugCalculator(Channel channel) {
    super(channel);
    channel.subscribe(this, Event.class);
  }

  public void onEvent(Event event) {
    System.out.println("event = " + event);
  }
}
```

Base class of all events

26

(Tough) Lessons Learned

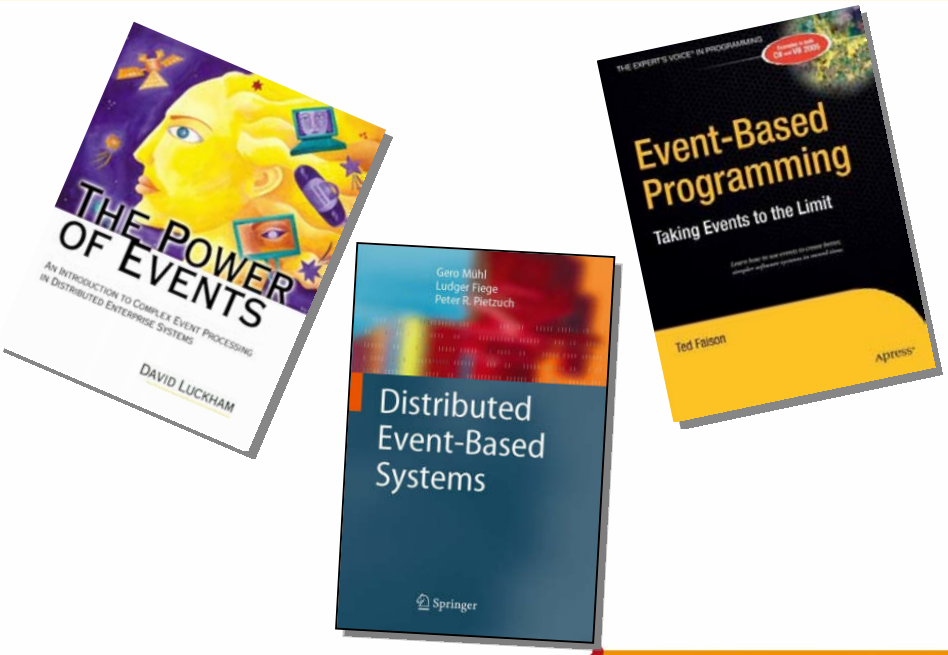
- **Must keep architectural big picture in mind**
- **Integration testing more critical – less compile time validation (the price of loose coupling)**
- **Tools essential**
  - **Event logger**
  - **Dependency visualization ("reverse MDA")**
- **Shared state not always avoidable. Can lead to hidden dependencies**
- **Make minimum necessary assumptions about sequence of events**
- **Loosely coupled systems harder to diagnose**

27

Side-By-Side

Call Stack	Event-Driven
Top-down	Bottom-up
Design-time composition	Run-time composition
Sequential	Parallel
Synchronous	Asynchronous
Predictive	Reactive
Transactional (Pessimistic)	Compensation / Retry (Optimistic)
Centralized state	Distributed state
Error handling simple	Error handling more complex
	Diagnostics more complex

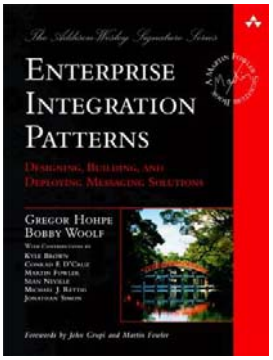
28



29

For More Information

- **Enterprise Integration Patterns**
  - **Addison-Wesley, 0-321-20068-3**
- **www.eaipatterns.com**
  - **Article: Programming without a Call Stack**
  - **Blog ("Ramblings")**



- **http://www.martinfowler.com/eaaDev/EventCollaboration.html**
- **http://www.martinfowler.com/eaaDev/EventSourcing.html**

30