Composition

Service-Oriented Architecture

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1 Composition of services

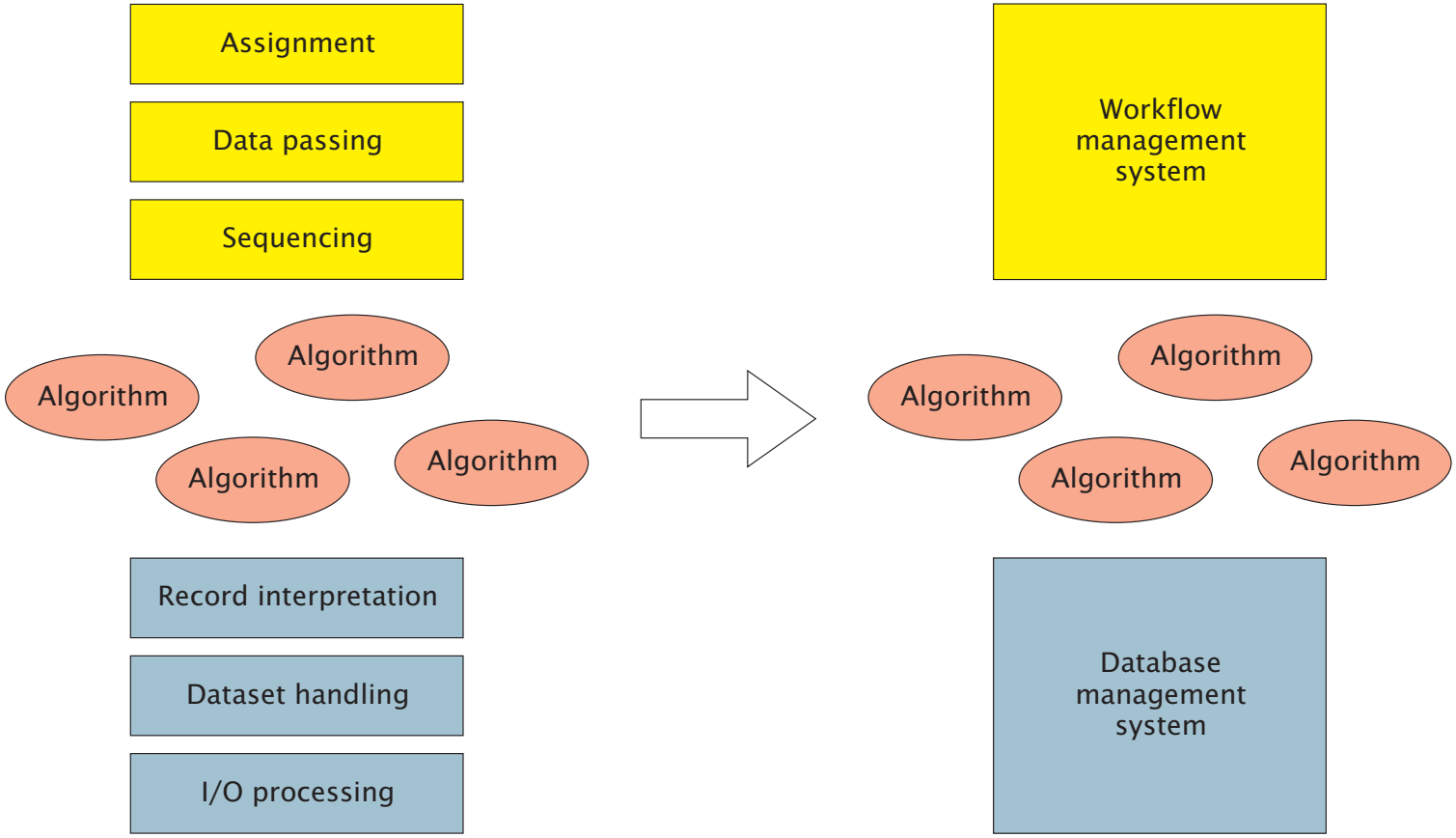
- services provide *platform- and language-independent access* to *software components*
- but these components are *isolated*: they need to be *assembled* into *service-oriented architectures*
- ideally, they should be recursively *composable* to form composite services in their own right
- *workflow* languages for scripting or ‘glue’ between individual services
- beyond mere *business protocol specifications* like RosettaNet, which are essentially paper specifications so can’t be automated and won’t scale
- BPMN, WSCI, WSFL, XLANG, BPEL...

1.1 Workflow

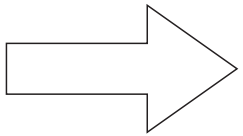
- *individual* services can be represented in WSDL
- but how should they be *combined*?
- textual documentation can explain the protocol; traditional programming language can implement it — but then the business process is *embedded in code*
- the process has value in its own right, and should be recorded separately as a *workflow*
- can then be stored, manipulated, and modified independently of individual activities
- ‘don’t let your business’s widget-making knowledge walk out of the door each evening in the chief widget-maker’s head’ (Virdell)
- agility is the key here (c.f. Sessions on MiG-15 vs F-86)

1.2 Removal of dependencies (Leymann and Roller)

DBMS provides independence from data *representation*;
workflow provides independence from control or data *flow*.



1.3 An architectural analogy



exogenous connectivity

1.4 Historical precedents: EAI, WfMS

- *enterprise application integration* (EAI)
- resolving heterogeneity, typically via asynchronous *message brokers*
- *workflow management systems* (WfMS): automating interactions
- origins in *office automation*: admin processes
- *production workflows*: from information between people to integration of systems
- often associated with *business process re-engineering*: assessment, analysis, modelling, definition, implementation
- service composition = EAI + WfMS

1.5 Sequencing

- control-dependencies between activities:
  predecessor must finish before successor can start
- data-dependencies between activities:
  output from predecessor is (transformed into) input to successor
- conditional constructions: internal or external choice
- time-out constructs

1.6 Exception handling

- consequences of exceptional conditions
- recovery sequences
- must return system to consistent state, wherever exception occurred
- at least as important as the ‘normal’ cases
- typically expands model by factor of 4 or 5!

1.7 Orchestration and choreography

- *orchestration*
  - describes procedure
  - instructs participants globally
  - imperative; centralized
  - typically deterministic: ‘must’
- *choreography*
  - describes protocol
  - constraints on interaction, but participants act locally
  - declarative; no ‘current state’
  - usually non-deterministic: ‘may’
- by analogy: orchestra has conductor, ballet does not

1.8 Compensation

- business processes are usually *long-running transactions*
- want to maintain ACID properties (atomicity, consistency, isolation, durability)
- . . . but cannot afford to use locking to achieve these
- therefore might have to compensate (as much as possible) for cancelled transactions
- compensations usually assume forward transaction completed successfully (no ‘partial compensations’)

1.9 Correlation

- business process typically involves some *conversation* between components
- therefore the same instance of a component should be involved throughout the process (at least logically)
- in the OO world, this is handled by *object references*
- but components should maintain no persistent state
- so subsequent messages in a workflow should be *correlated*
- ‘customer reference number’ or ‘case number’

1.10 Polarity

- WSDL operations are of four kinds:

  one-way: port receives `<input>` messages only

  request-response: port receives `<input>` then sends `<output>`

  notification: port sends `<output>` message only

  solicit-response: port sends `<output>` then receives `<input>`

- one-way and request-response operations are *incoming*, solicit-response and notification operations *outgoing*
- workflow specification will match up ports; obviously, matched ports must have operations of opposing *polarities*
- WSDL does not restrict port types to aggregating operations of a common polarity; XLANG spec argues that *allowing a mixture of incoming and outgoing operation types in a port type is highly undesirable*

1.11 Workflow management

- if workflow model is sufficiently *precise and complete*, then *workflow engine* can execute process description automatically
- workflow model dictates ordering, dataflow, compensation, etc
- well-established R&D area (*Workflow Management Coalition* (`http://www.wfmc.org/`) since early 1990s; OMG *Workflow Management Facility Specification* since 1996, version 1.2 in 2000)
- eg *megaprogramming*: module assembly (Wiederhold, 1992)
- now being assimilated into SOA worldview

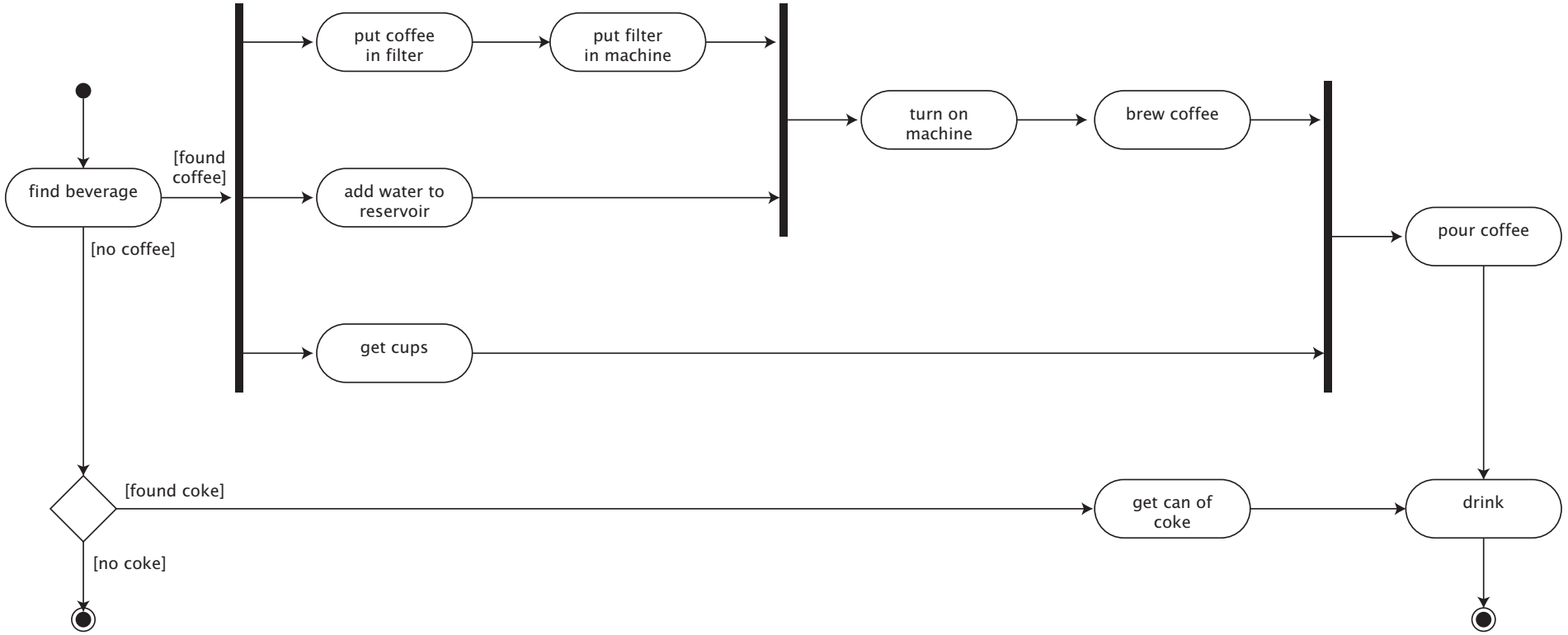
1.12 WS-related standards for workflow

- *Web Services Flow Language* (WSFL) (IBM; 2001)
- *XLANG* (Microsoft; 2001)
- *Web Services Choreography Interface* (WSCI) (BEA, Intalio, SAP, Sun; 2002)
- combined into *Business Process Execution Language for Web Services* (BPEL4WS, or just BPEL) (IBM, Microsoft, BEA, SAP, Siebel; 2003), to be submitted to OASIS
- various ad-hoc and vendor-specific graphical notations; OMG standard *Business Process Modeling Notation* (BPMN) an alternative

2 UML activity diagrams for recording workflow

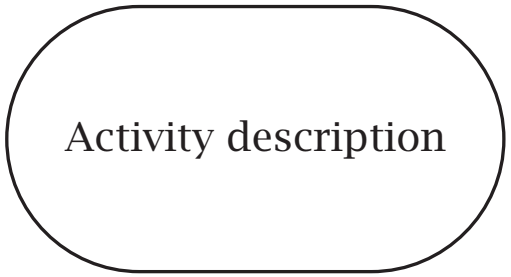
- activity diagrams illustrate *time-* or *data-dependencies* between *activities*
- based on Petri nets
- some similarities with flowcharts, but are also well-suited to presenting *parallel* sequences of activities
- mainly used in UML to document complex operations
- . . . but also useful for expressing *business workflows*
- approach based on Fowler, *UML Distilled*
- (there's now a draft UML profile for BPEL)

2.1 Example activity diagram (after UML spec)



2.2 Activities

- an atomic action, eg execution of an operation
- with duration, and with possible interruption points
- denoted by an oval: straight top and bottom, round ends

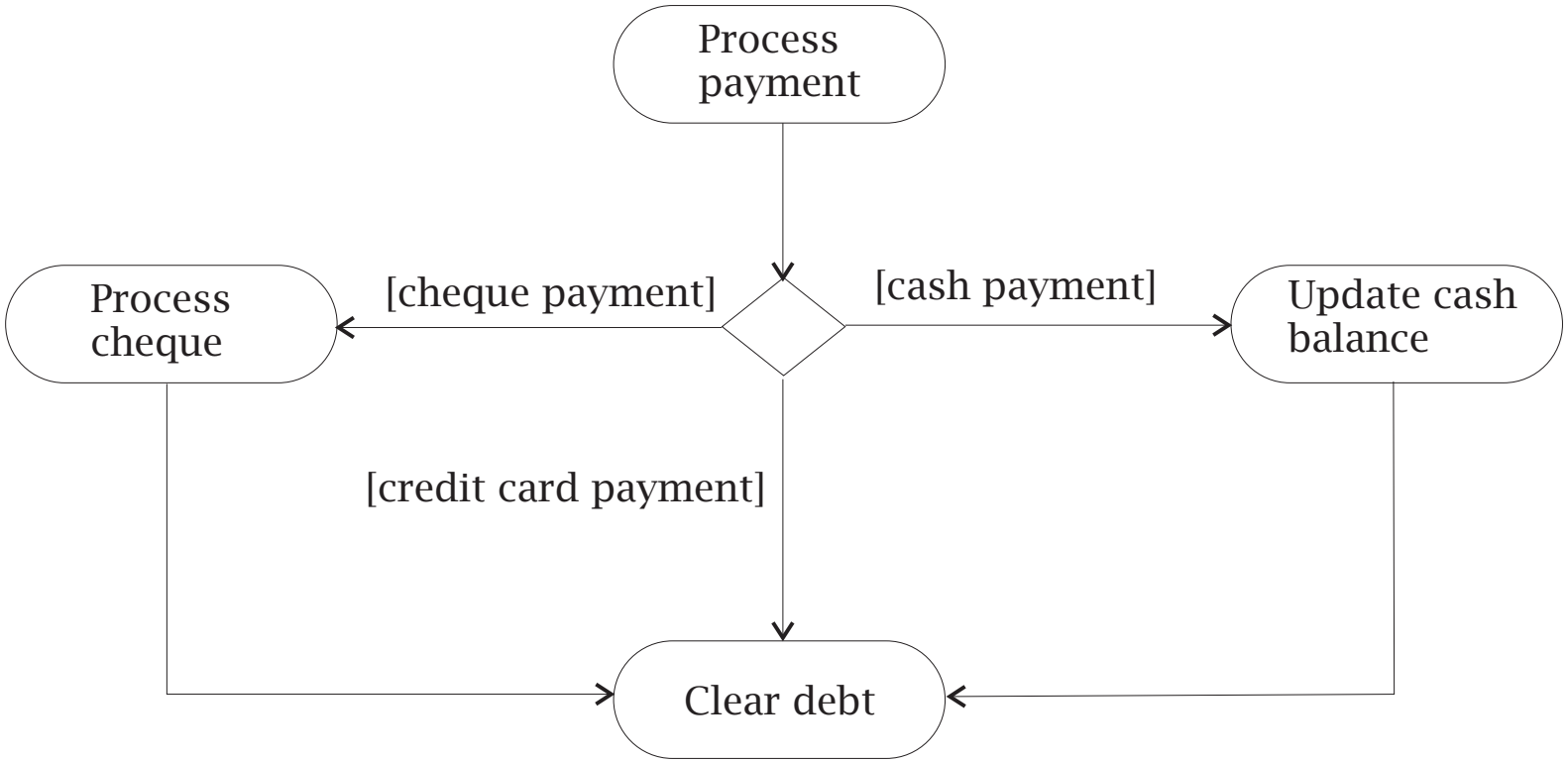


2.3 Transitions

- movement from one activity to another
- normally occurs when all the actions of an activity have been completed
- may occur when an event triggers the exit from a particular activity
- indicated by an arrow between activities

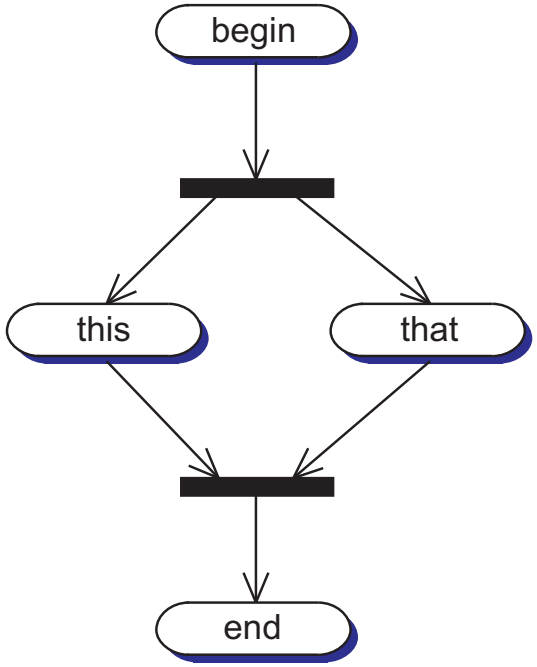
2.4 Decision points

- a point where the exit transition from an activity can branch in alternative directions depending on a condition



2.5 Synchronization bars

- split a transition into multiple paths, and combine multiple paths into a single transition
- *fork* vertices have a single incoming transition
- *join* vertices have a single outgoing transition
- in general, synchronization bar may have multiple incoming and outgoing transitions
- forks and joins should match up ('token balance')



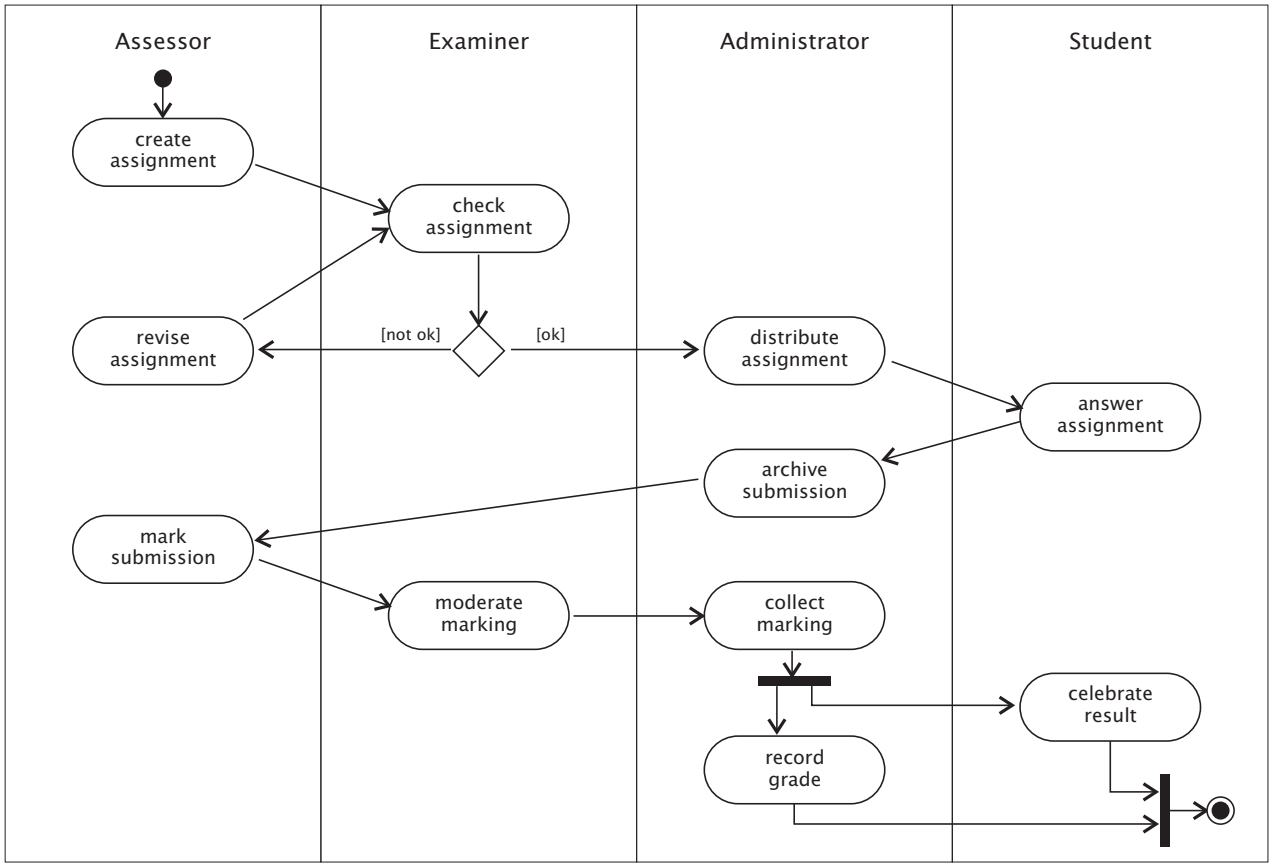
2.6 Start and end states

- *start state* is the entry point to a flow
- only one start state allowed

- end states indicate the exit point from a flow
- multiple end states are allowed

2.7 Swimlanes

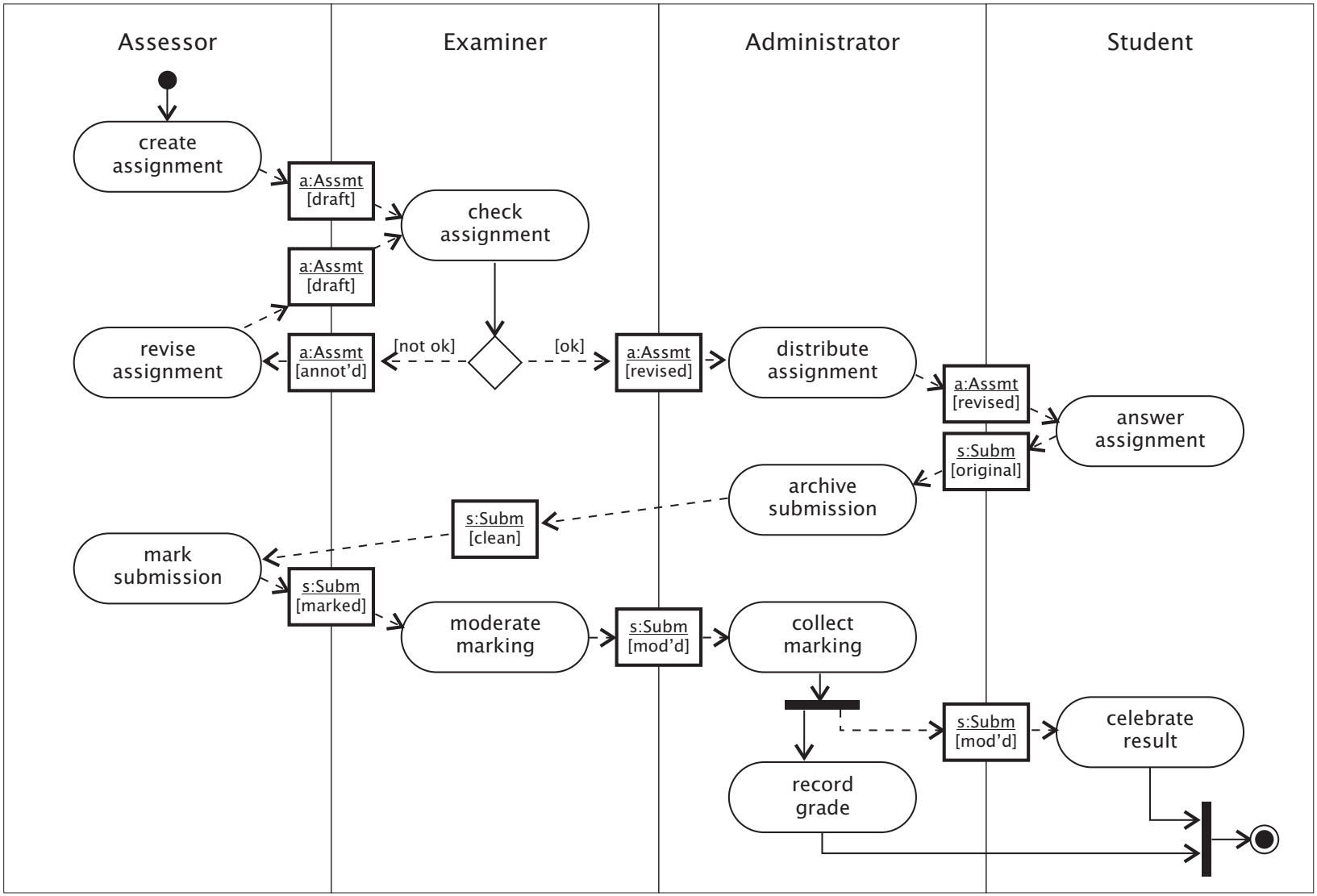
- partition an activity diagram into the responsibilities of different entities



2.8 Dataflow

- transitions between activities represent *control dependencies*: one activity must complete before another can start
- workflows also have *data dependencies*: one activity produces a result that another requires
- UML activity diagrams allow *object flow* as well as *control flow*
- dependent data is shown as an object icon (rectangle with underlined name and type)
- *dependencies* shown as dashed arrows from generating activity to object, and from object to consuming activity(s)
- same object may occur multiple times in an activity diagram, typically in different *states* (shown in square brackets after object name)

2.9 Example of object flow



3 Business Process Modelling Notation (BPMN)

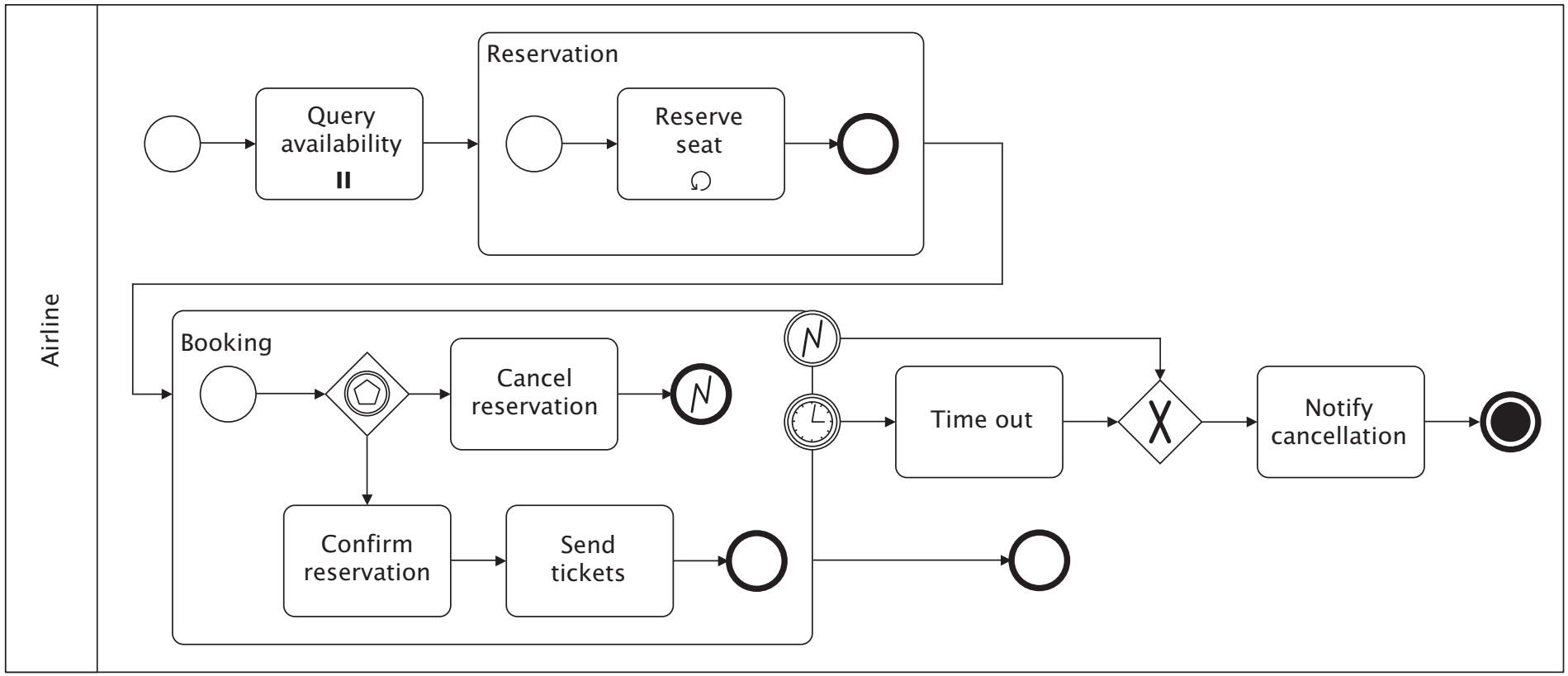
- graphical notation specifically for workflow
- developed by Business Process Management Initiative, now part of OMG
- currently v1.1; working on v2.0 (two different ones!)
- spec also defines mapping to BPEL
- my student Peter Wong translating to CSP

3.1 BPMN constructs

Very briefly:

- flow objects
  - event (start, end)
  - activity
  - gateway (branching)
- connecting objects
  - sequence flow (control)
  - message flow (data)
- swimlanes
- data object

3.2 BPMN example



4 WSCI

- BEA Systems, Intalio, Sun, SAP
- describes the flow of messages exchanged with a web service
- expressed in terms of temporal and logical dependencies between messages
- features sequencing rules, correlation, exception handling and transactions
- allows client to understand how to interact with service, and to anticipate its behaviour
- ‘operating manual’ for a web service
- not an executable workflow language

4.1 Questions answered by WSCI

- can messages be sent and/or received in any order?
- what rules govern the sequencing of messages?
- what is the relationship between incoming and outgoing messages?
- is there a ‘start’ and an ‘end’ to a sequence of messages?
- can a sequence be partially undone?

4.2 Features provided by WSCI

- *message choreography*: ordering rules
- *transaction boundaries and compensation*, allowing participation in distributed transactions
- *exception handling*, reactions to exceptional circumstances
- *thread management*: capability for concurrent conversations, and correlation of these
- *properties and selectors* that govern observable behaviour
- *connections* between consumers and producers
- *dynamic participation*: how target identity is selected

5 WSFL

- IBM's contribution to standardization (Frank Leymann et al.)
- two modes of use:

  flow model describes *usage pattern* of collection of web services

  global model describes distributed *interaction pattern* between collection of web services

- supports recursive composition: each flow model or global model can in turn be represented as a web service, and further composed

5.1 Composition

- one use case for WSFL
- enterprise implements a business process by composing existing web services
- existing base services already provided by other vendors (or by this one)
- coordination of these services described in WSFL
- eg providing a FAÇADE for a complex collection of services
- advert in service repository would attract offers from consumers

5.2 Parametrization

- a second use case for WSFL, a variation on the first
- abstract away from particular implementations of base services; leave *plug links* for later binding
- still use WSFL to describe the coordination
- describes *exports* (services provided) and *imports* (services required)
- appropriate for describing service *brokers*; eg comparative shopping service acts as a broker between shoppers and shops
- advert in service repository would attract two kinds of offers: from producers and consumers

6 XLANG

- Microsoft's contribution, part of BizTalk (EAI for .Net)
- sequential and parallel flow constructs
- internal and external choice
- long running transactions with compensations
- custom correlation of messages
- exception handling
- abstraction from detail: *opaque values*

7 WS-BPEL

- formerly *Business Process Execution Language for Web Services*
- a combination of IBM's WSFL (graph-oriented control flow) and Microsoft's XLANG (structured control flow)
- input also from BEA, Siebel, SAP, Sun
- envisage two usage patterns: for describing *abstract processes* (describing interaction patterns but not data transformations) and *executable processes*
- common core, with extensions for each usage pattern

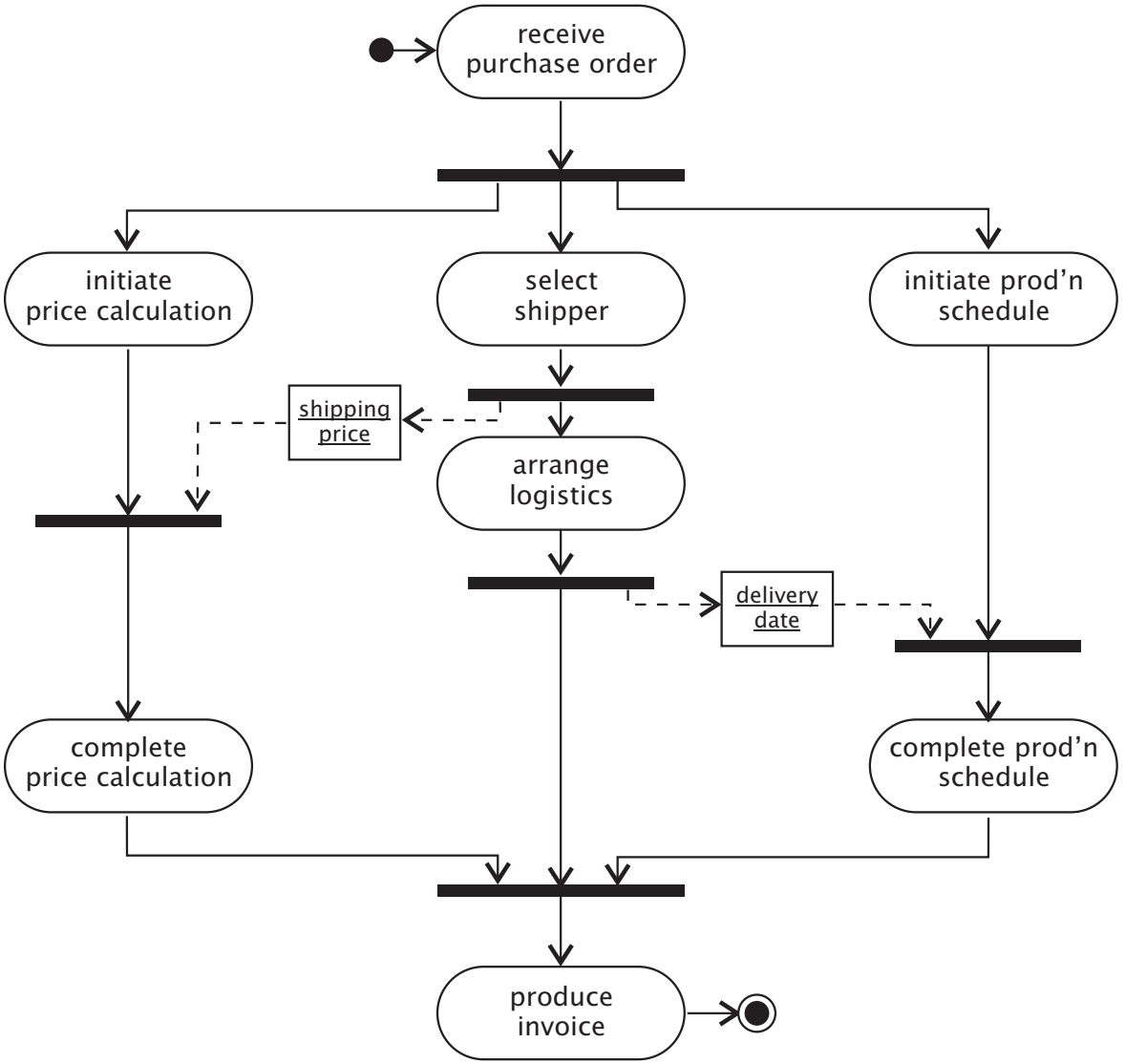
7.1 Executable processes vs business protocols

- *executable business process* captures participants' exact behaviour
- *business protocol* is an abstraction of this: describes message exchanges but not specific data
- business protocol involves *transparent data* (relevant to public aspects) and *opaque data* (relevant only to private back-end systems)
- analogous to network packet's *control fields* and *payload*
- from business protocol point of view, opaque data is nondeterministically chosen
- a contribution from XLANG (which provided only business protocols, but anticipated extensions to executable processes)

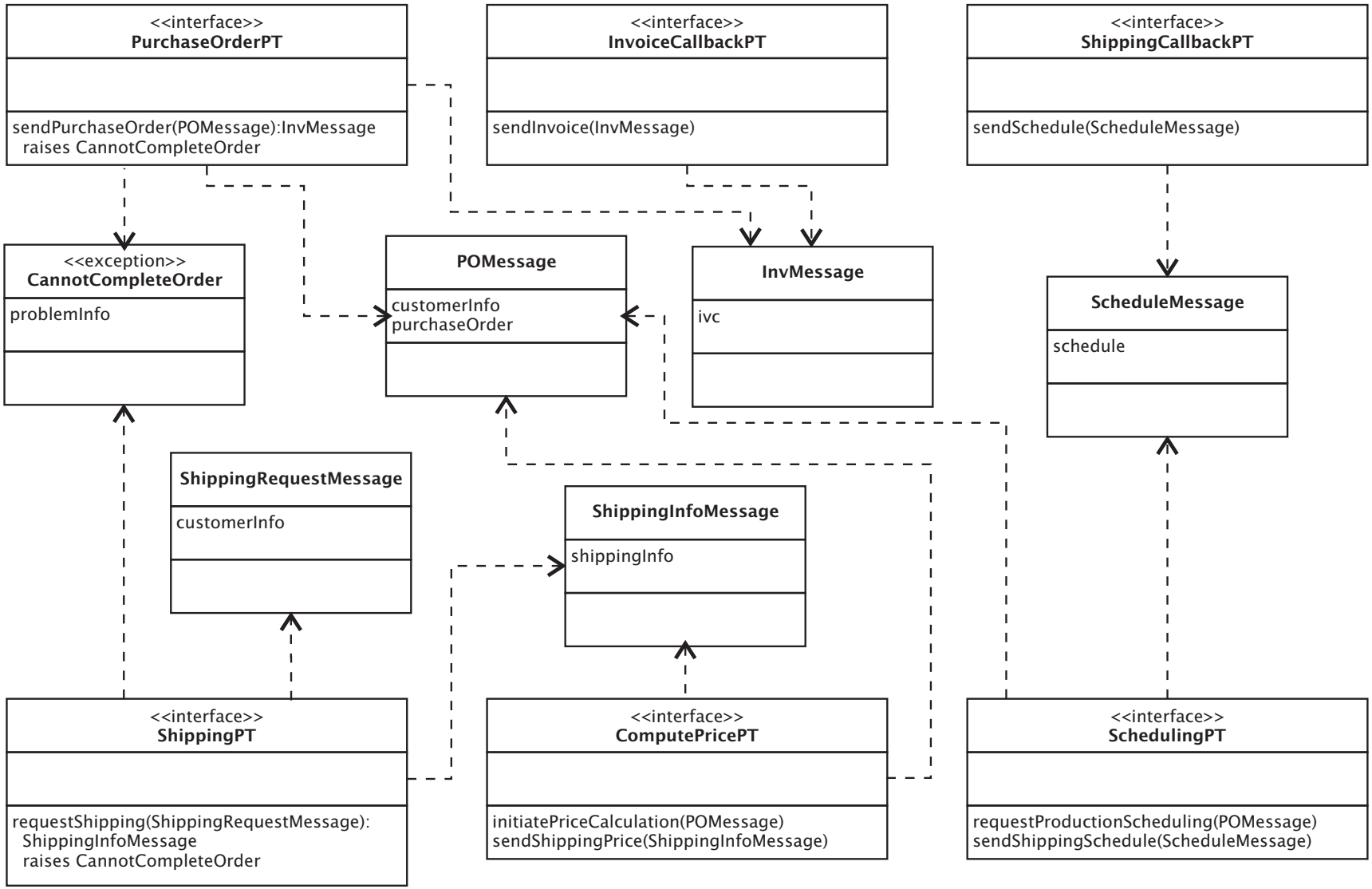
7.2 Simple example

- purchase order system
- system receives purchase order from customer
- price is calculated, shipping arranged, production scheduled (in parallel)
- on completion, invoice is produced
- choice of shipper feeds into price calculation
- shipping date feeds into production schedule
- see appendix for WSDL and BPEL

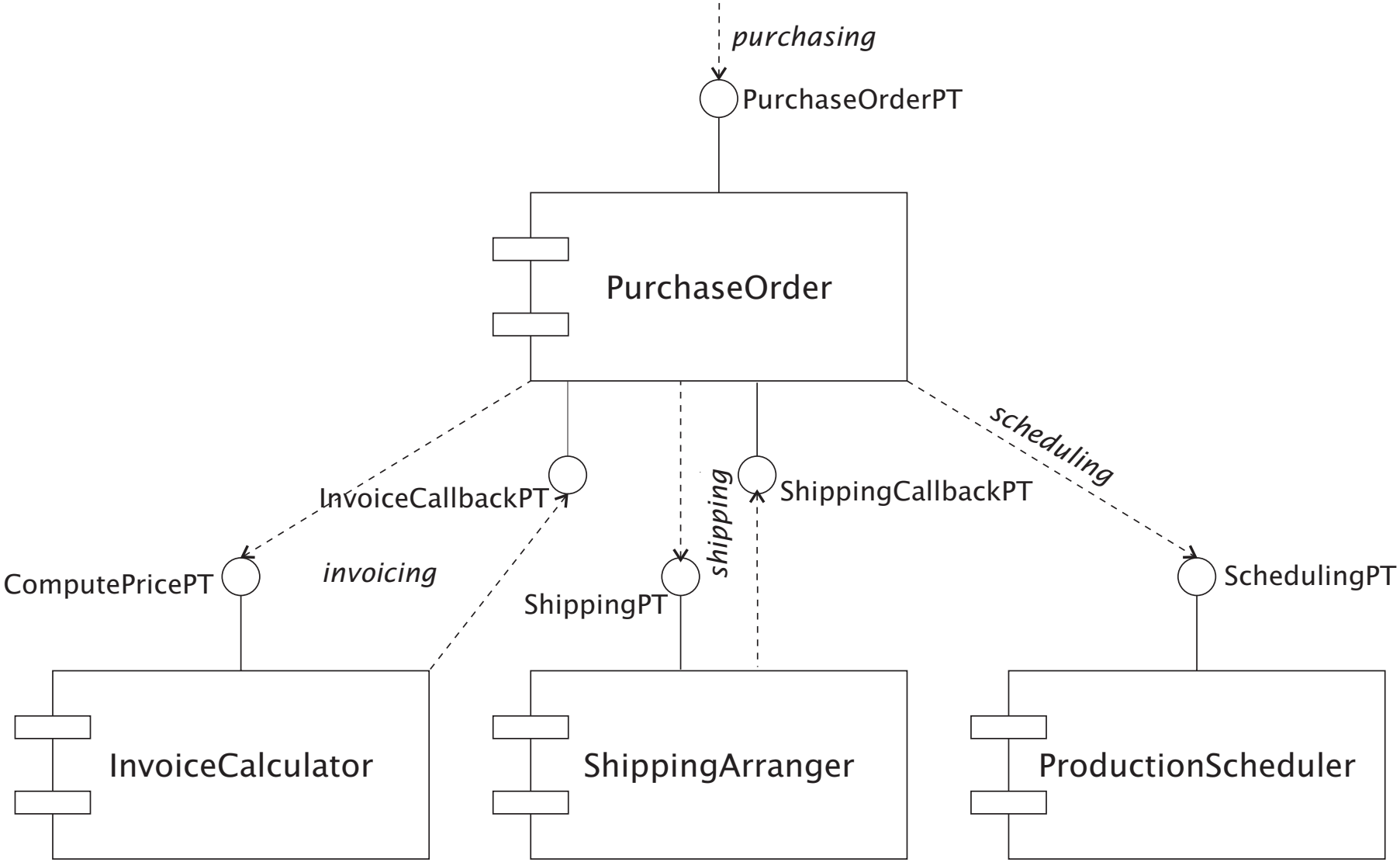
7.3 Abstract activity diagram for purchase orders



7.4 Messages and port types



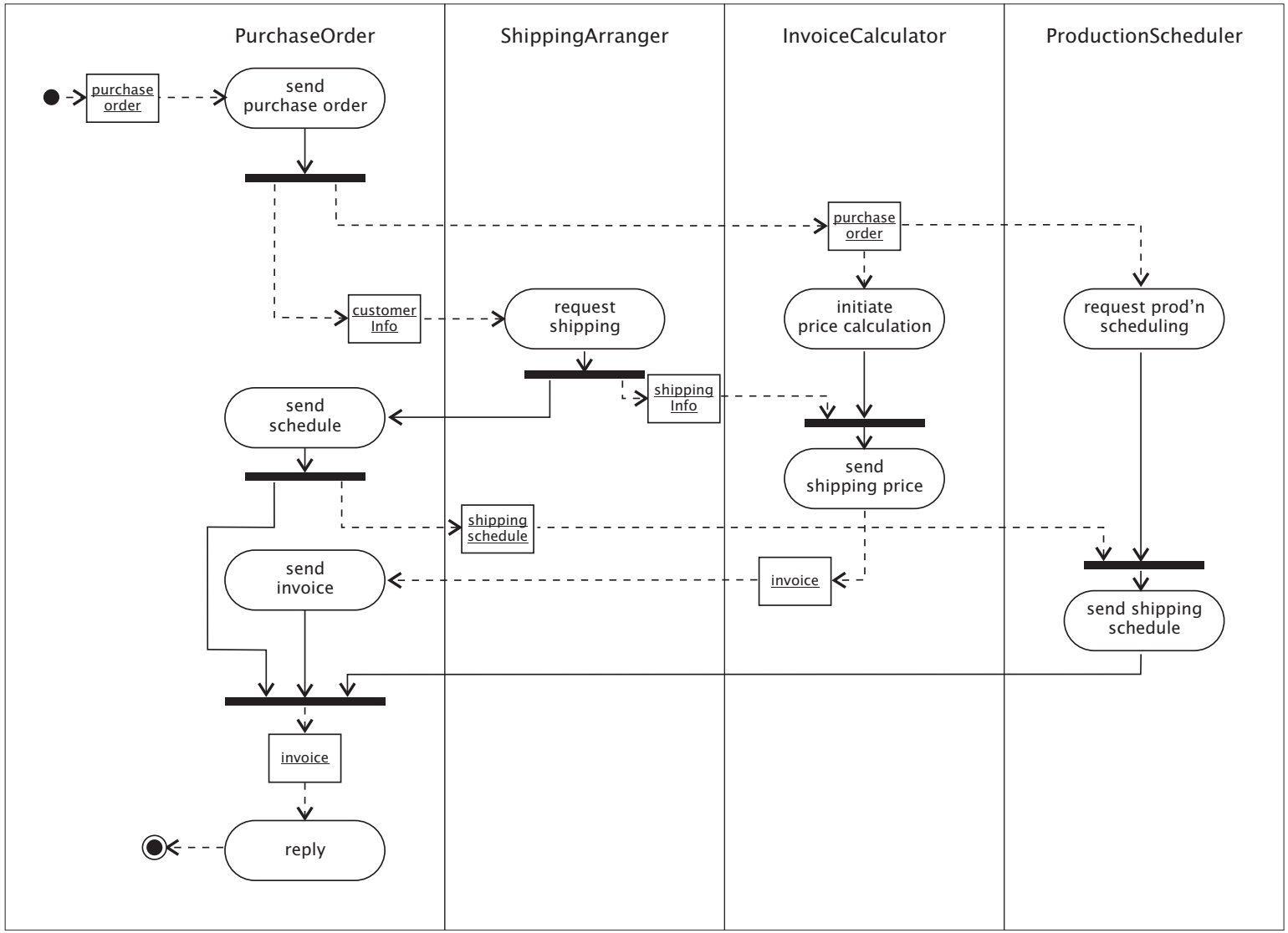
7.5 Partner links



7.6 Notes on partner links

- interactions between business process and external parties
- *partner link type* defines one (for unidirectional links) or two (for bidirectional) *roles* of corresponding *port types*
- (here, no requirements are placed on the customer using the *PurchaseOrder* component, and no requirements are placed on this for using the *ProductionScheduler* component; for an asynchronous service, customer would have to provide a callback interface)
- *partner links* instantiate partner link types, specifying *myRole* (played by this process) and/or *partnerRole* (played by external party)
- bindings of actual partners to external roles are omitted
- would expect opposites to match up, but WS-BPEL supports only incoming

7.7 Coordination



7.8 Notes on coordination

- dataflow links by global *variables*
- *fault handlers* for exceptions (omitted in activity diagram for simplicity)
- `<sequence>` element for sequential ordering
- `<flow>` element for concurrent execution
- `<link>` elements for extra dependencies within `<flow>`
- simple `<assign>`ments shown; more complex ones available
- control constructs (`<switch>`, `<while>`) also available
- `<receive>` for messages consumed by process, and `<reply>` for responses
- `<invoke>` for messages sent to external parties

8 Reflection

- BPEL represented in XML is very ugly; not worth exploring here
- tools should do all the relevant translating for you: UML to BPEL translators exist, for example
- we can use this approach to describe abstract and concrete coordination processes; the concrete coordination process has to run somewhere
- design activity is the crucial piece — UML profiles can help

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tea	tea	tea	tea	
Web Services	Qualities	Objects	Semantic Web	