Applying UML and Patterns

**An Introduction to
Object-oriented Analysis
and Design
and Iterative Development**

Part III Elaboration Iteration I – Basic^2

Chapter 15
UML Interaction Diagrams

Introduction

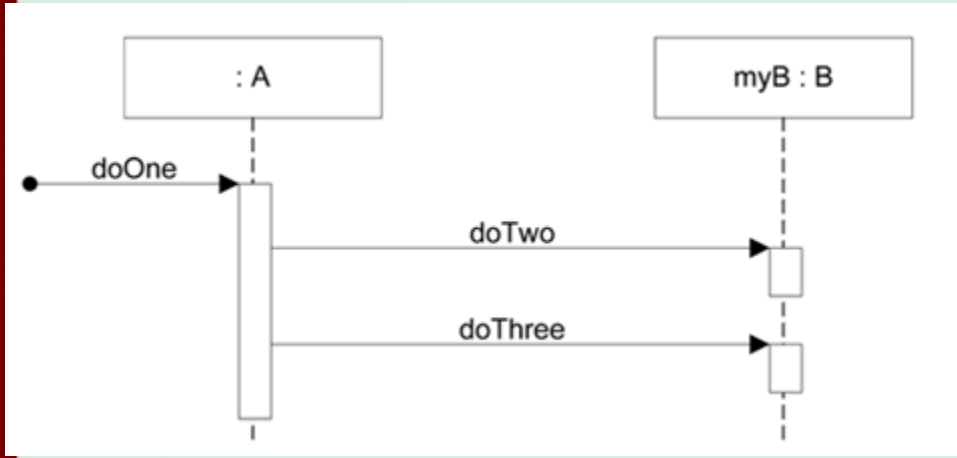
- The UML includes **interaction diagrams** to illustrate how objects interact via messages.
  - **sequence** and **communication** interaction diagrams.
- This chapter introduces the notation - view it as a reference to skim through - while subsequent chapters focus on a more important question: What are key principles in OO design?

Sequence and Communication Diagrams

- The term interaction diagram is a generalization of two more specialized UML diagram types:
  - sequence diagrams
  - communication diagrams
- Both can express similar interactions
- A related diagram is the interaction overview diagram;
  - provides a big-picture overview of how a set of interaction diagrams are related in terms of **logic and process-flow**.
  - It's new to UML 2, and so it's too early to tell if it will be practically useful.

Sequence Diagram

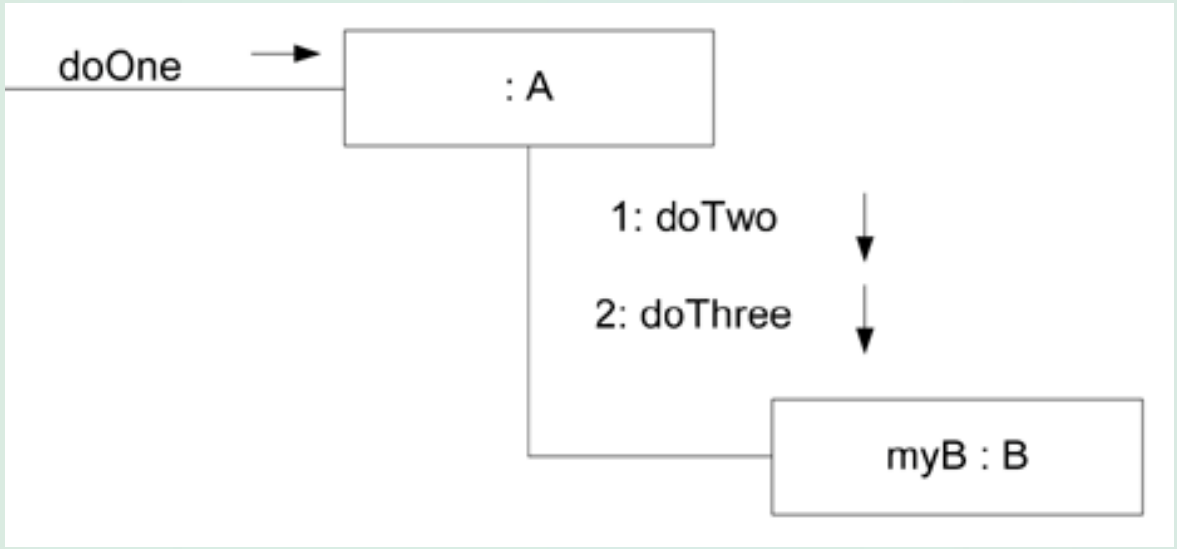
- Sequence diagrams illustrate interactions in a kind of fence format, in which each new object is added to the right,




```
public class A {
   private B myB = new B();
   public void doOne() {
        myB.doTwo();
        myB.doThree();
   }
   // …
}
```

Communication Diagram

- Communication diagrams illustrate object interactions in a graph or network format, in which objects can be placed anywhere on the diagram



Strengths and Weaknesses 1

- Sequence diagrams have some advantages over communication diagrams
  - UML specification is more sequence diagram centric - more thought and effort has been put into the notation and semantics.
    - Thus, tool support is better and more notation options are available
  - it is easier to see the call-flow sequence with sequence diagrams simply read top to bottom.
    - With communication diagrams we must read the sequence numbers, such as "1:" and "2:"

Strengths and Weaknesses 2

- Advantages of communication diagrams
  - communication diagrams have advantages when applying "UML as sketch" to draw on walls (an Agile Modeling practice) because they are much more space-efficient.
  - boxes can be easily placed or erased anywhere horizontal or vertical.
  - In contrast, new objects in a sequence diagrams must always be added to the right edge, which is limiting as it quickly consumes and exhausts right-edge space on a page (or wall)

Strengths and Weaknesses 3

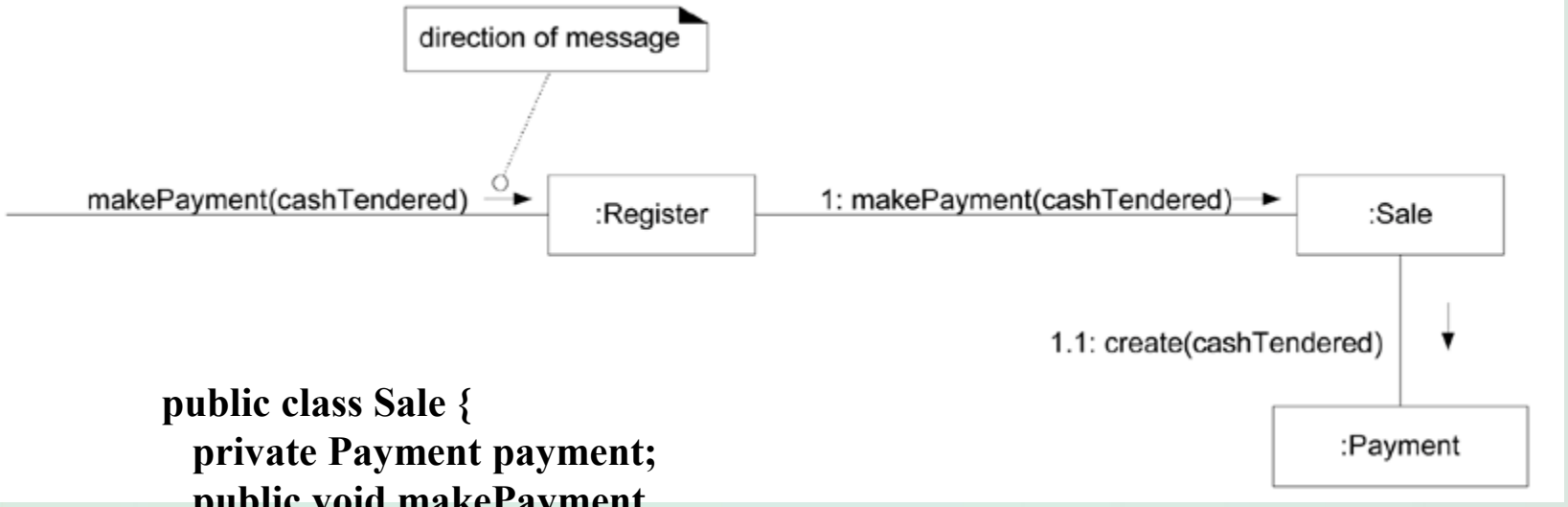
Type	Strengths	Weaknesses
sequence	clearly shows sequence or time ordering of messages large set of detailed notation options	forced to extend to the right when adding new objects; consumes horizontal space
communication	space economicalflexibility to add new objects in two dimensions	more difficult to see sequence of messages fewer notation options

Example Sequence Diagram

1. The message *makePayment* is sent to an instance of a Register. The sender is not identified.
2. The Register instance sends the *makePayment* message to a Sale instance.
3. The Sale instance creates an instance of a Payment.

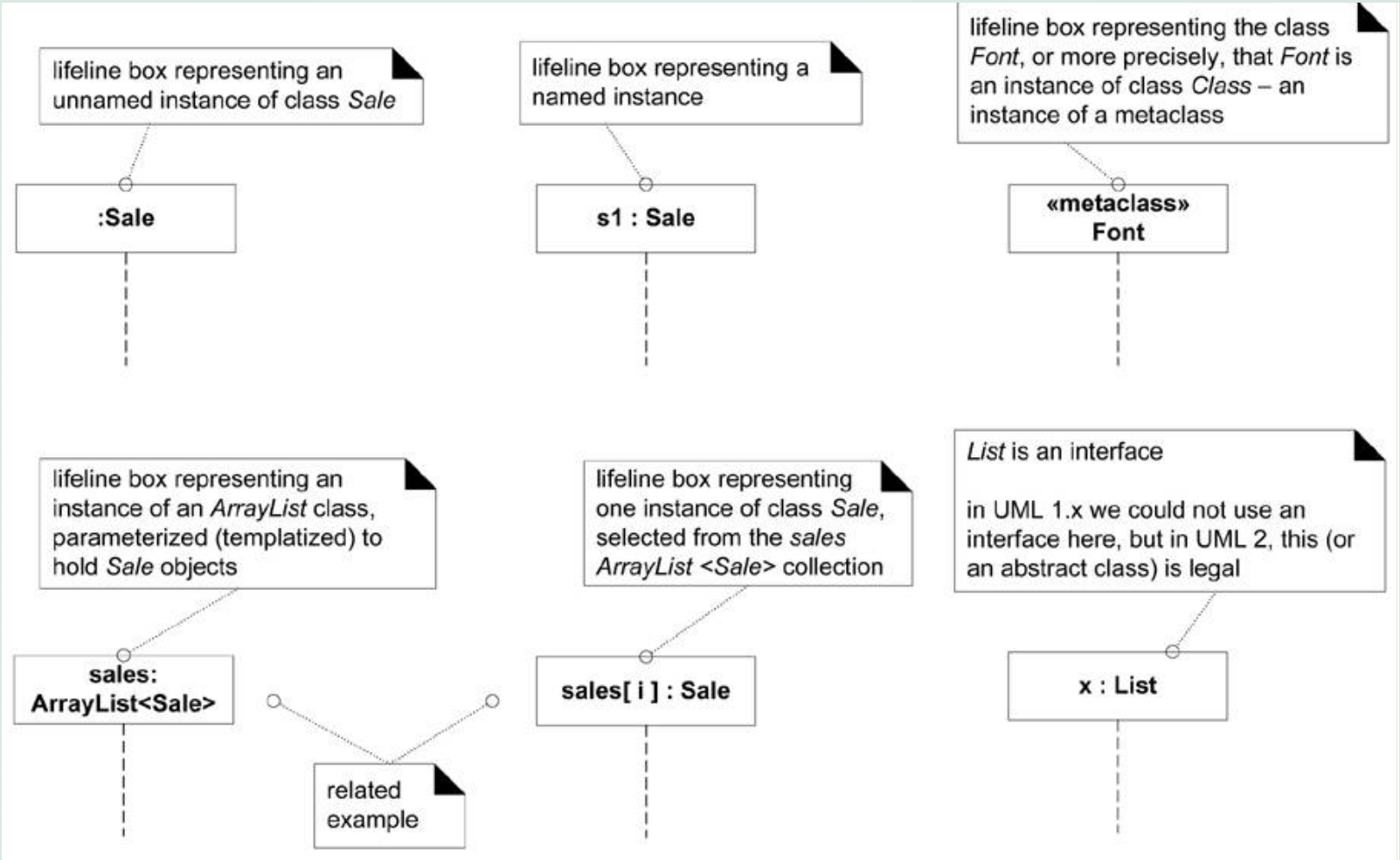
What might be some related code for the Sale class and its *makePayment* method?

Example Communication Diagram




```
public class Sale {
   private Payment payment;
   public void makePayment
          ( Money cashTendered ) {
      payment = new Payment
          ( cashTendered );
      //…
   }
   // …
}
```

Common UML Interaction Diagram Notation



Lifeline boxes to show participants in interactions

Basic Message Expression Syntax

- UML has a standard syntax for these message expressions

  return = message(parameter : parameterType) : returnType

- Parentheses are usually excluded if there are no parameters, though still legal.
- Type information may be excluded if obvious or unimportant.
- For example:
  - *initialize(code)*
  - *initialize*
  - *d = getProductDescription(id)*
  - *d = getProductDescription(id:ItemID)*
  - *d = getProductDescription (id:ItemID) : ProductDescription*

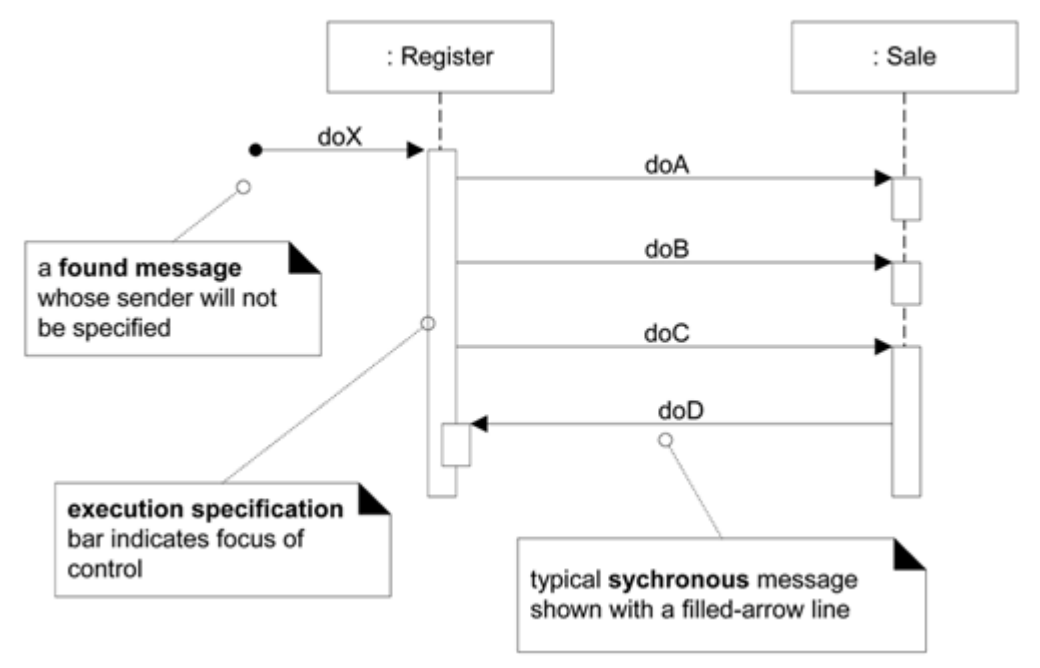
Singleton Objects

- In the world of OO design patterns, there is one that is especially common, called the Singleton pattern
  - There is only one instance of a class instantiated - never two

Basic Sequence Diagram Notation

- **Lifeline Boxes and Lifelines**
  - In sequence diagrams the lifeline boxes include a vertical line extending below them - these are the actual lifelines.
  - Although virtually all UML examples show the lifeline as dashed (because of UML 1 influence), in fact the UML 2 specification says it may be solid or dashed.
- **Messages**
  - Each (typical synchronous) message between objects is represented with a message expression on a filled-arrowed solid line between the vertical lifelines
  - The time ordering is organized from top to bottom of lifelines.

Message and Focus of Control 1



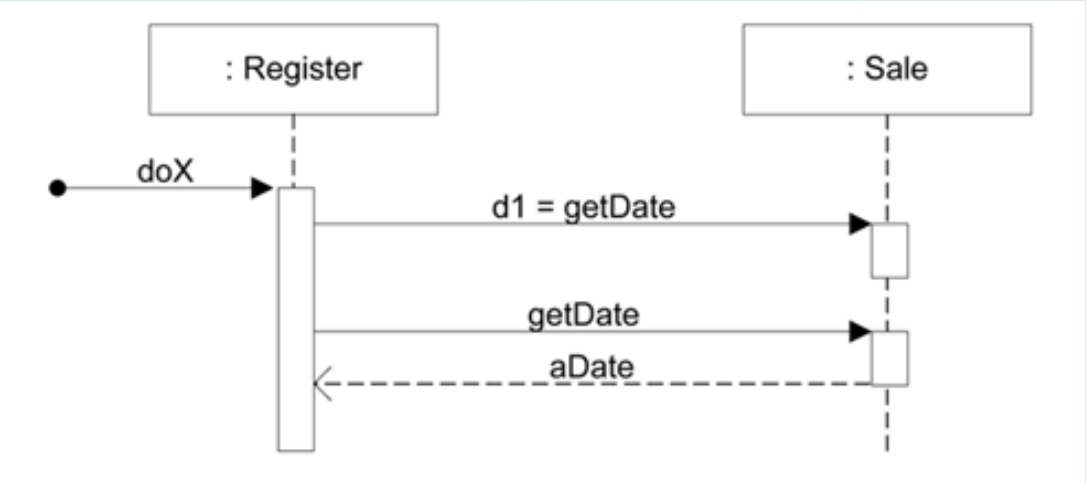
- found message:
  - the sender will not be specified, is not known, or that the message is coming from a random source

Message and Focus of Control 2

- Sequence diagrams may also show the focus of control using an execution specification bar (previously called an activation bar or simply an activation in UML 1).
  - The bar is optional.
  - Guideline: Drawing the bar is more common (and often automatic) when using a UML CASE tool, and less common when wall sketching.

Illustrating Reply or Returns

- There are two ways to show the return result from a message:
  - Using the message syntax
    - *returnVar = message(parameter).*
  - Using a reply (or return) message line at the end of an activation bar.



Creation of Instances

- The arrow is filled if it's a regular synchronous message (such as implying invoking a Java constructor), or open (stick arrow) if an asynchronous call.
  - The message name *create* is not required - anything is legal - but it's a UML idiom.
- Object Lifelines and Object Destruction

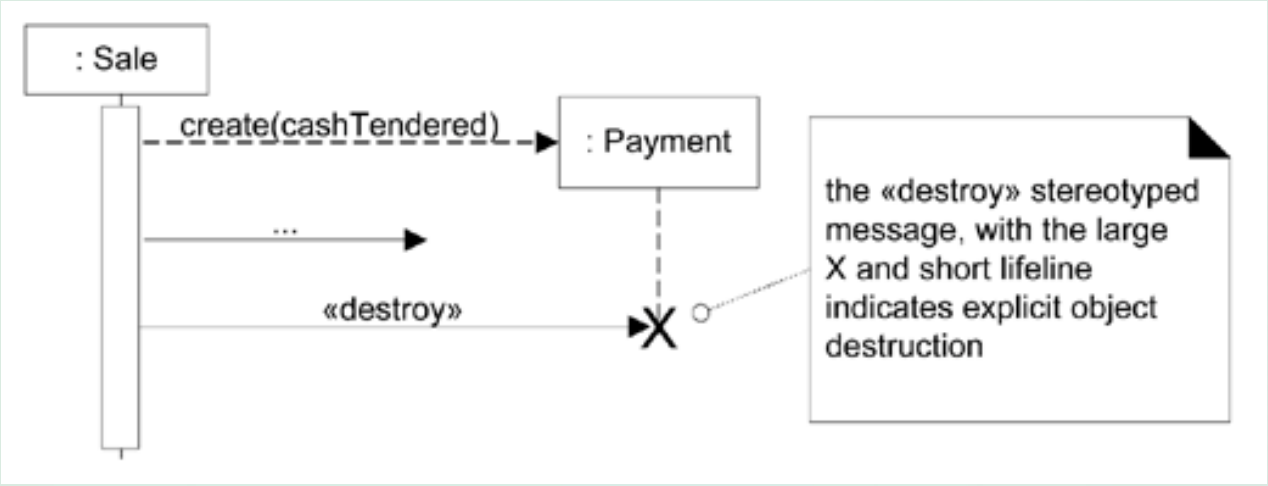


Diagram Frames in UML Sequence Diagrams 1

- To support conditional and looping constructs (among many other things), the UML uses frames.
  - Frames are regions or fragments of the diagrams;
  - they have an operator or label (such as loop) and a guard (conditional clause).

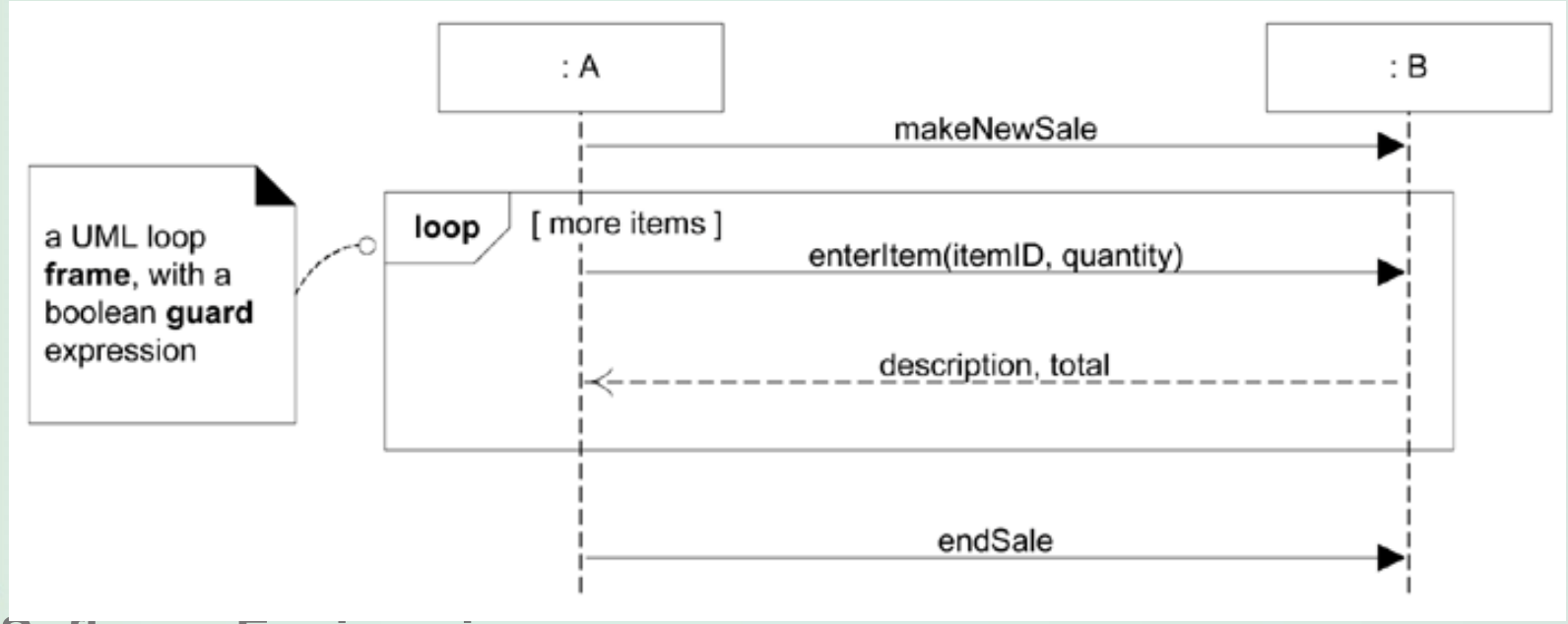
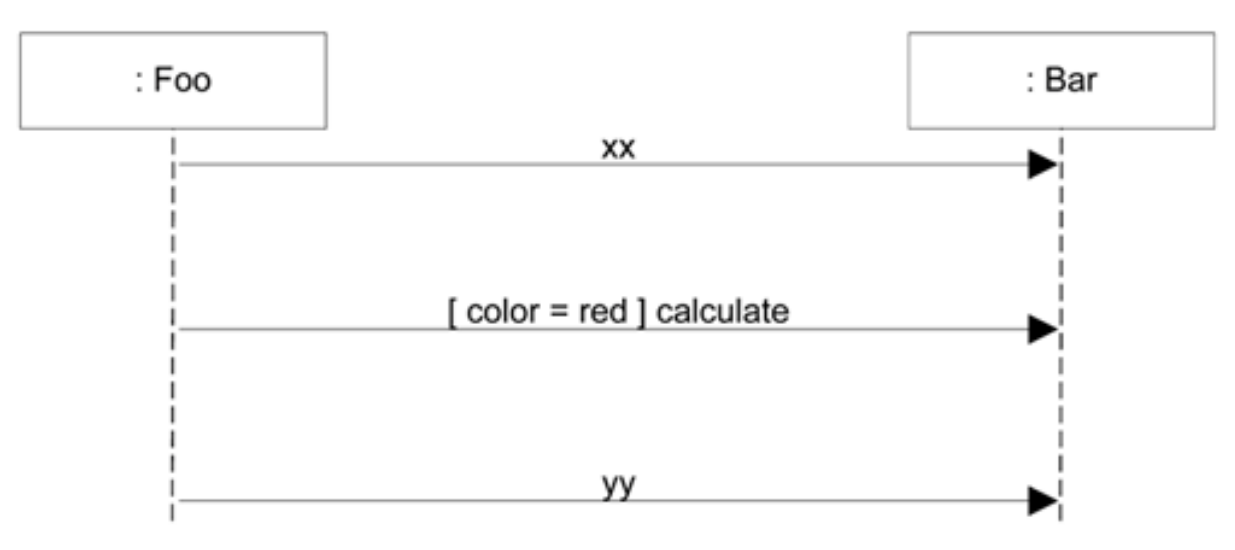


Diagram Frames in UML Sequence Diagrams 2

Frame Operator	Meaning
alt	Alternative fragment for mutual exclusion conditional logic expressed in the guards.
loop	Loop fragment while guard is true. Can also write *loop(n)* to indicate looping n times. There is discussion that the specification will be enhanced to define a *FOR* loop, such as *loop(i, 1, 10)*
opt	Optional fragment that executes if guard is true.
par	Parallel fragments that execute in parallel.
region	Critical region within which only one thread can run.

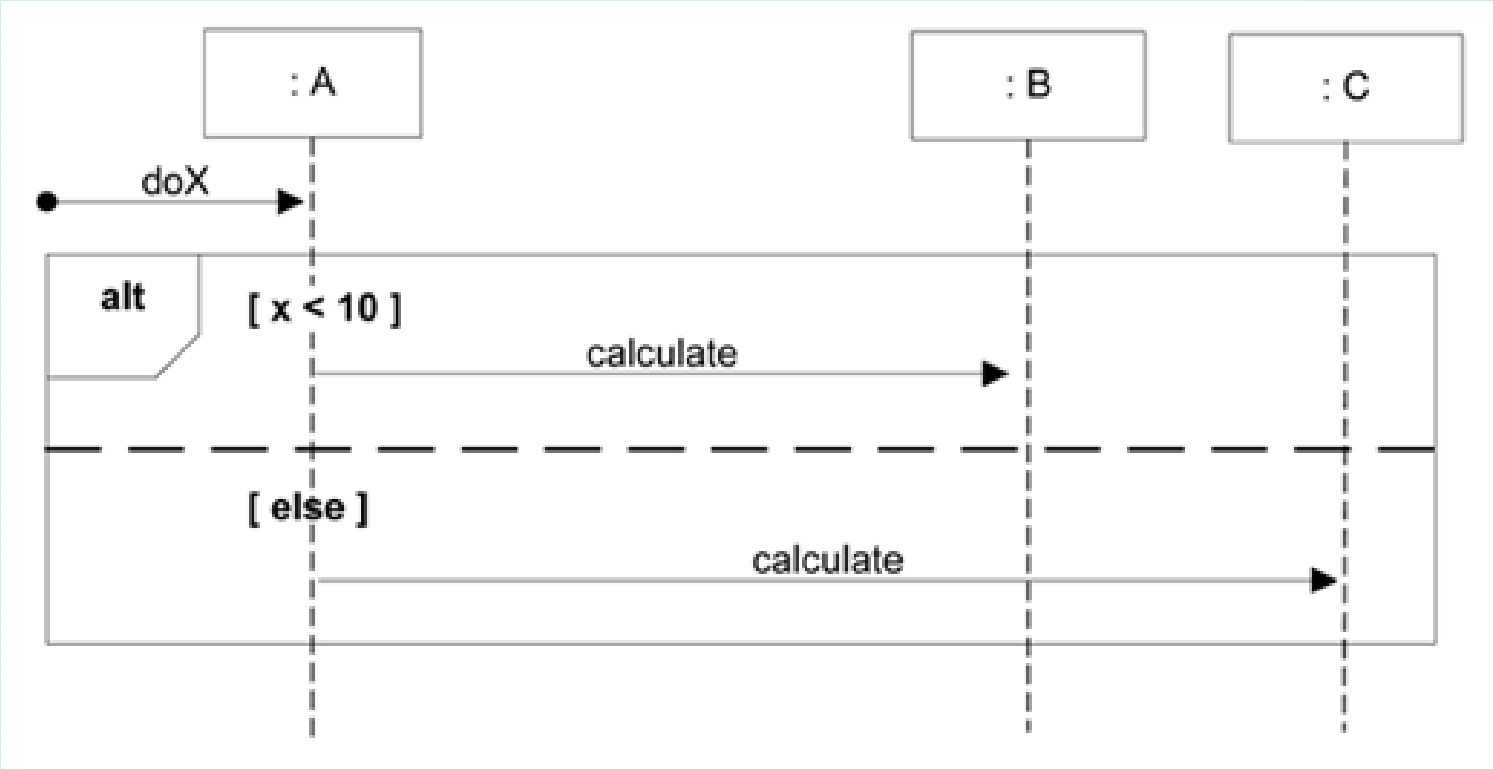
Condition message

- Use UML 1 style only for simple single messages when sketching

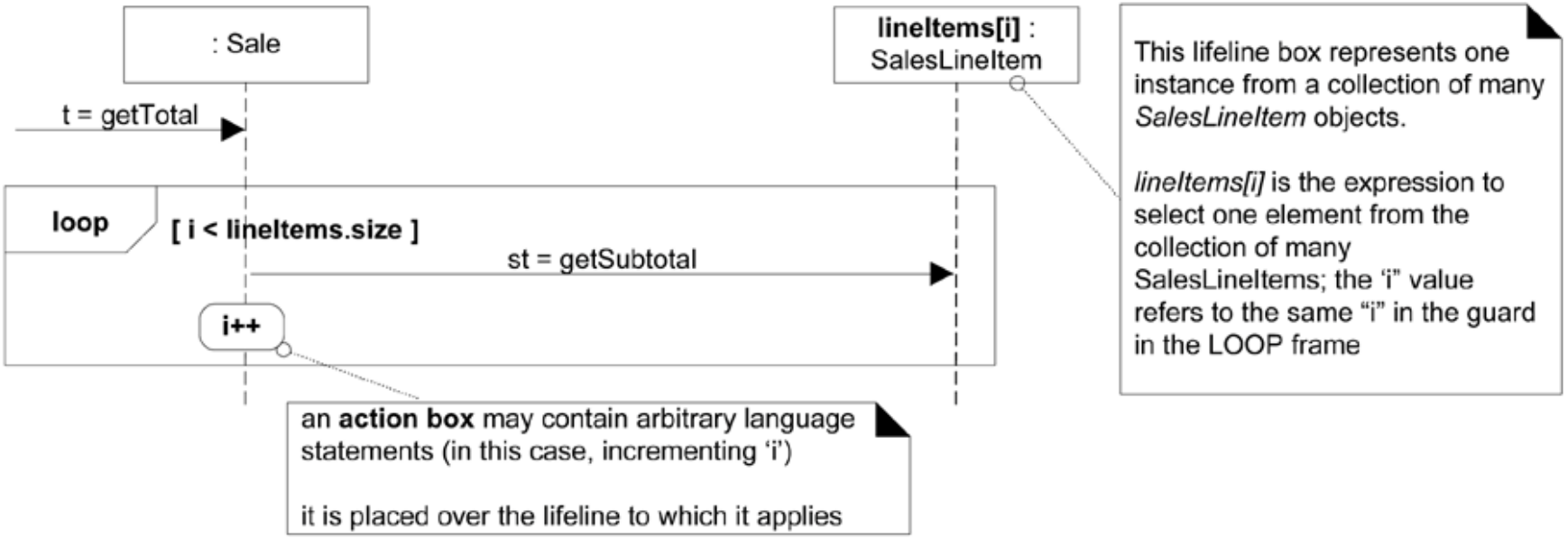


Mutually Exclusive Conditional Messages

- An ALT frame is placed around the mutually exclusive alternatives



Iteration Over a Collection 1



- A common algorithm is to iterate over all members of a collection (such as a list or map), sending the same message to each.
- Often, some kind of iterator object is ultimately used, such as an implementation of *java.util.Iterator* or a C++ standard library iterator, although in the sequence diagram that low-level "mechanism" need not be shown in the interest of brevity or abstraction.

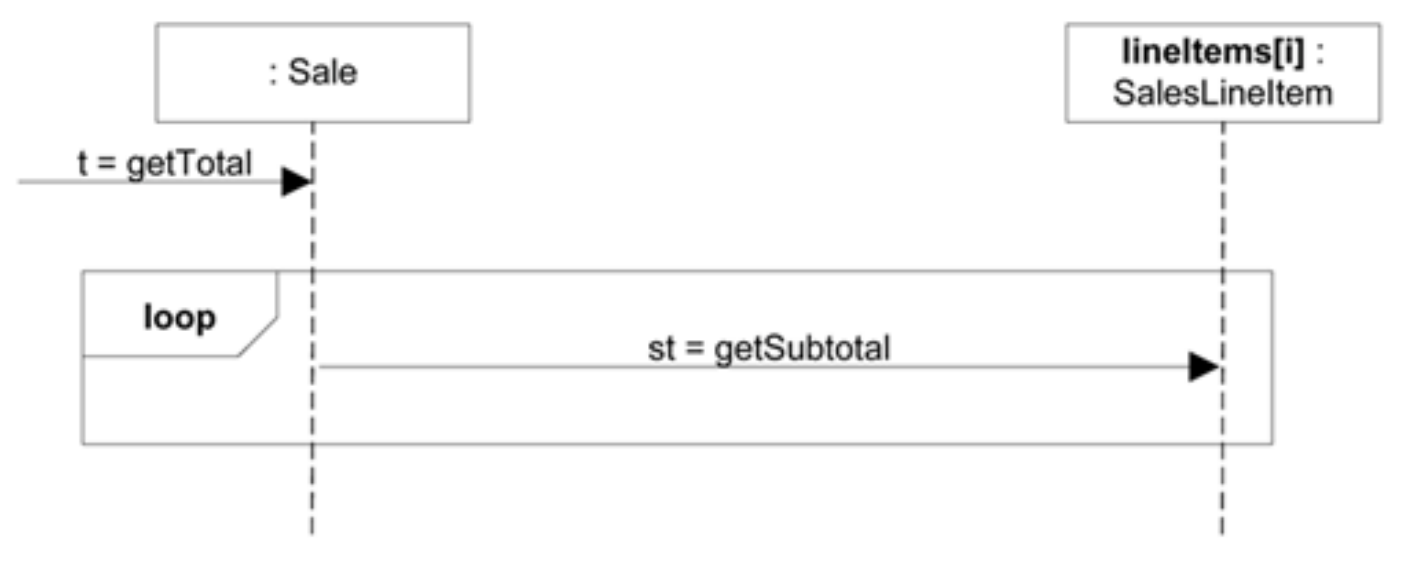
Iteration Over a Collection 2

- The selector expression is used to select one object from a group. Lifeline participants should represent one object, not a collection.

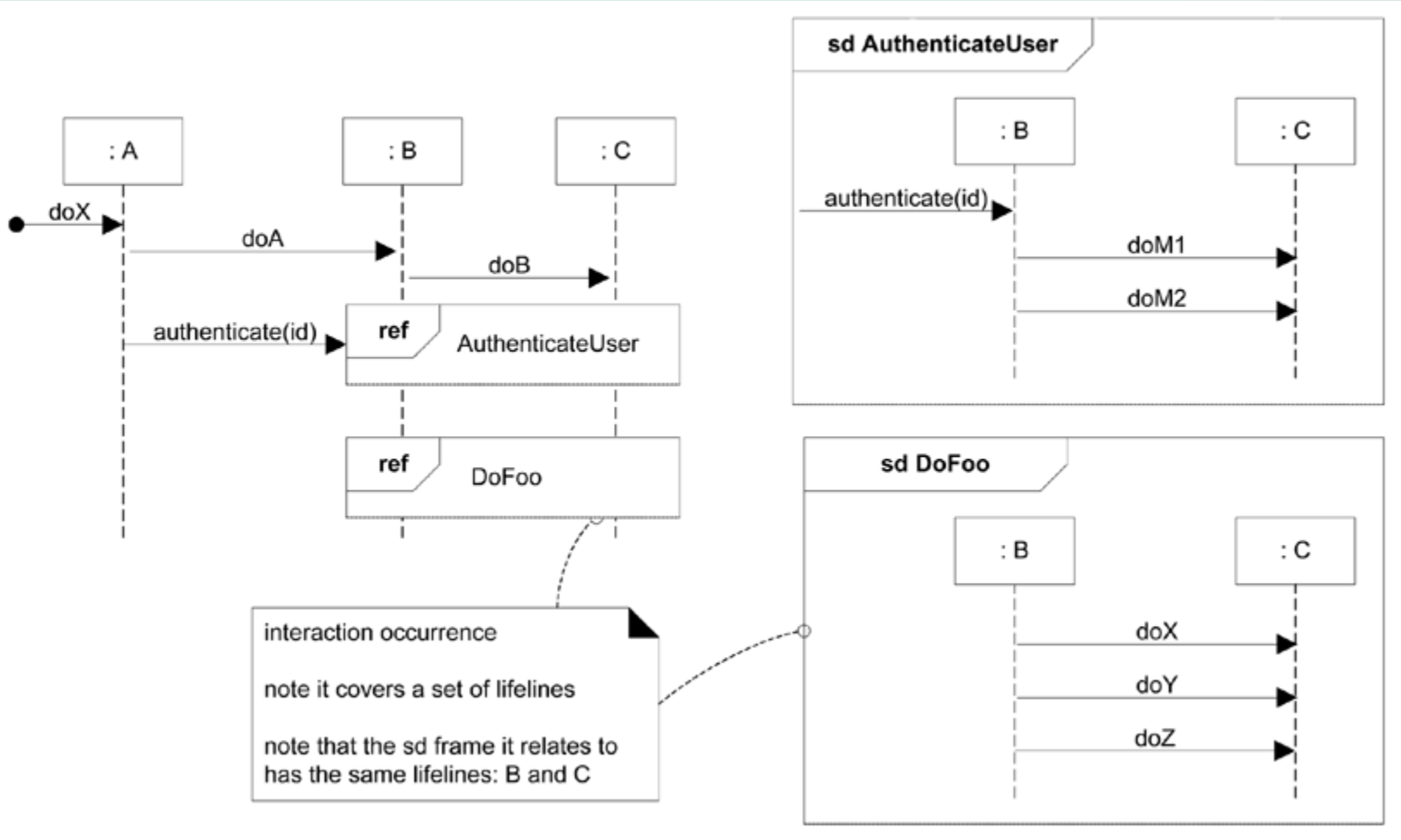
```
public class Sale {
  private List<SalesLineItem> lineItems = new ArrayList<SalesLineItem>();
  public Money getTotal() {
    Money total = new Money();
    Money subtotal = null;
    for ( SalesLineItem lineItem : lineItems ) {
       subtotal = lineItem.getSubtotal();
       total.add( subtotal );
    }
    return total;
    }
    // …
}
```

Iteration Over a Collection 3

- Another variation is shown below
  - The intent is the same, but details are excluded.
  - A team or tool could agree on this simple style by convention to imply iteration over all the collection elements



Relating Interaction Diagrams 1



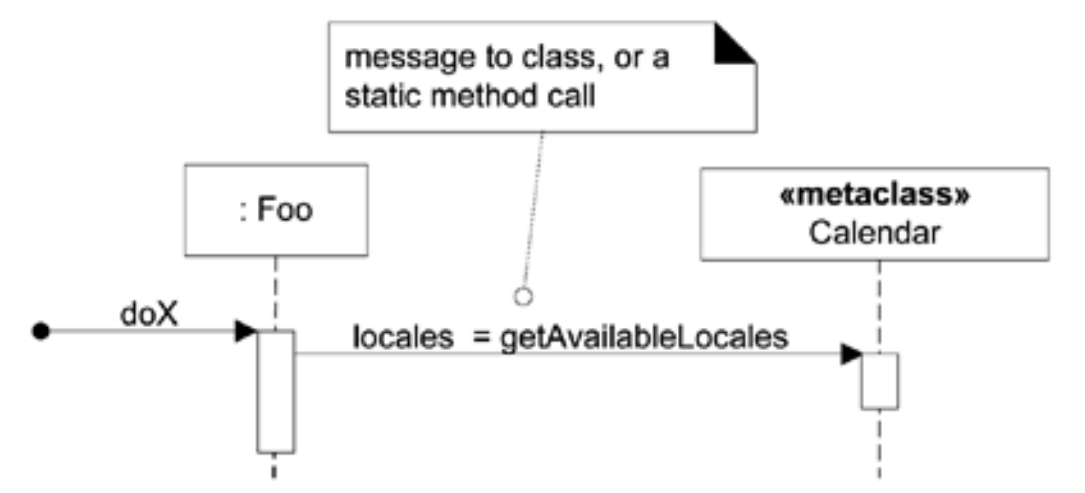
Relating Interaction Diagrams 2

- An interaction occurrence (also called an interaction use) is a reference to an interaction within another interaction.
  - for example, when you want to simplify a diagram and factor out a portion into another diagram, or there is a reusable interaction occurrence.
  - UML tools take advantage of them, because of their usefulness in relating and linking diagrams.

Metaclass 1

- You can show class or static method calls by using a lifeline box label that indicates the receiving object is a class, or more precisely, an instance of a metaclass
- in Java and Smalltalk, all classes are conceptually or literally instances of class Class;
- in .NET classes are instances of class Type. The classes Class and Type are metaclasses, which means their instances are themselves classes.
- A specific class, such as class Calendar, is itself an instance of class Class. Thus, class Calendar is an instance of a metaclass! It may help to drink some beer before trying to understand this.

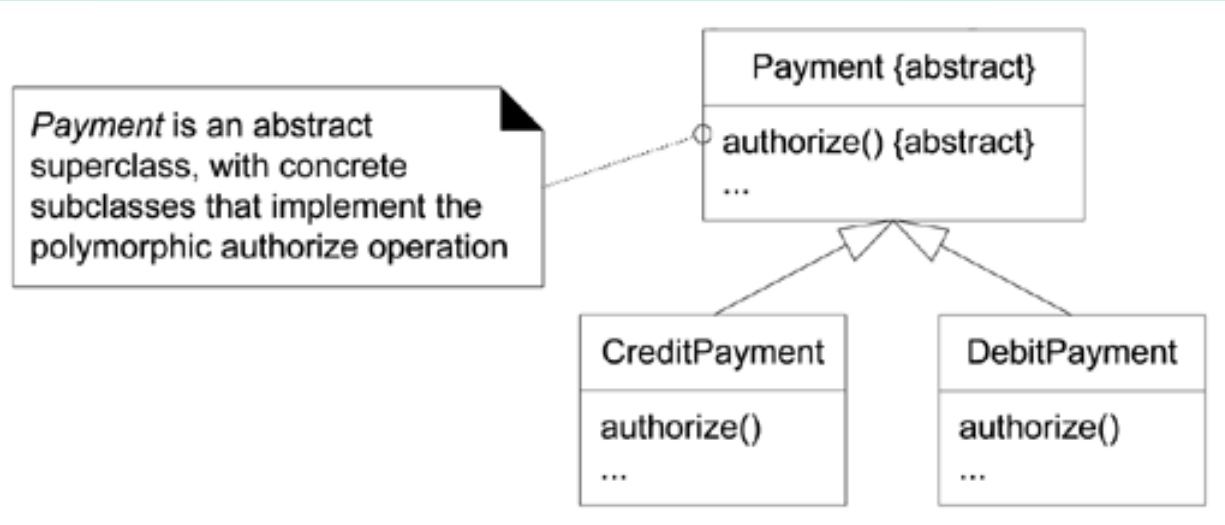
Metaclass 2




```
public class Foo {
   public void doX() {
      // static method call on class
      Calendar Locale[] locales = Calendar.getAvailableLocales();
          // …
      }
      // …
}
```

Polymorphic Messages and Cases

- How to show it in a sequence diagram? That's a common UML question.
  - To use multiple sequence diagrams - one that shows the polymorphic message to the abstract superclass or interface object, and then separate sequence diagrams detailing each polymorphic case, each starting with a found polymorphic message



Asynchronous and Synchronous Calls

- An asynchronous message call does not wait for a response; it doesn't block.
- They are used in multi-threaded environments such as .NET and Java so that new threads of execution can be created and initiated.
- In Java, for example, you may think of the *Thread.start* or *Runnable.run* (called by Thread.start) message as the asynchronous starting point to initiate execution on a new thread

Conti.

a stick arrow in UML implies an asynchronous call

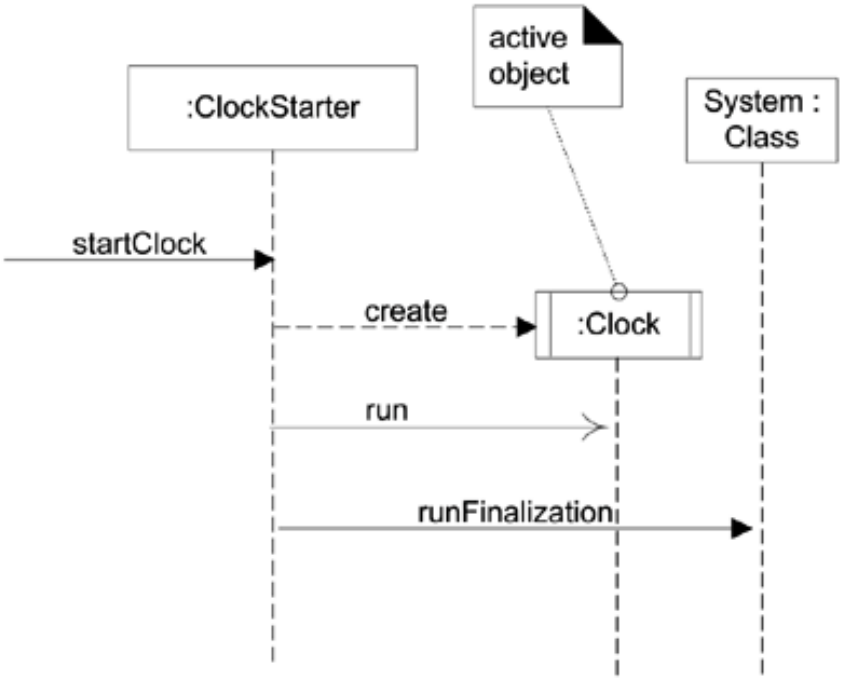
a filled arrow is the more common synchronous call

In Java, for example, an asynchronous call may occur as follows:

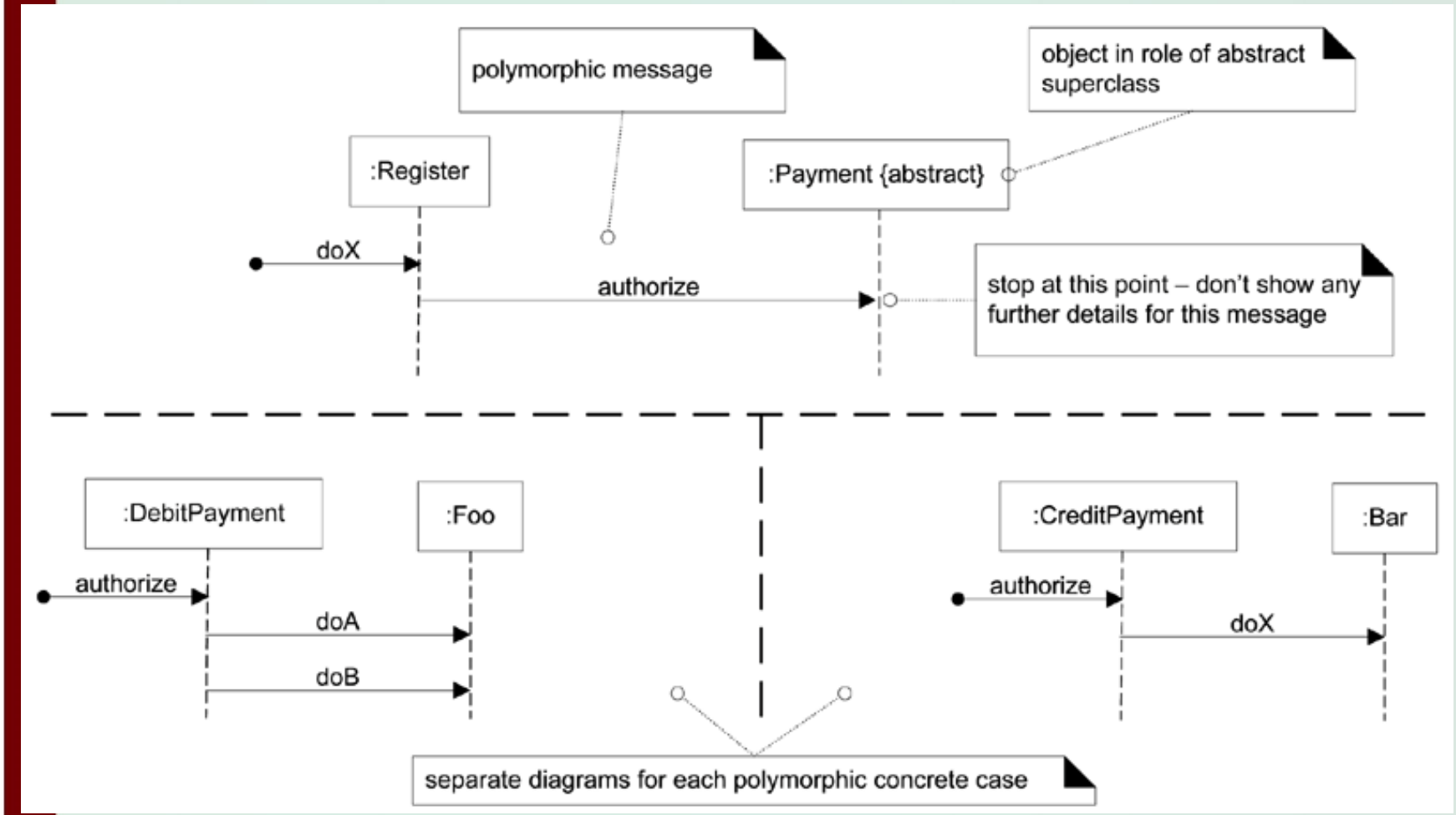
```
// Clock implements the Runnable interface
Thread t = new Thread( new Clock() );
t.start();
```

the asynchronous *start* call always invokes the *run* method on the *Runnable* (*Clock*) object

to simplify the UML diagram, the *Thread* object and the *start* message may be avoided (they are standard "overhead"); instead, the essential detail of the *Clock* creation and the *run* message imply the asynchronous call

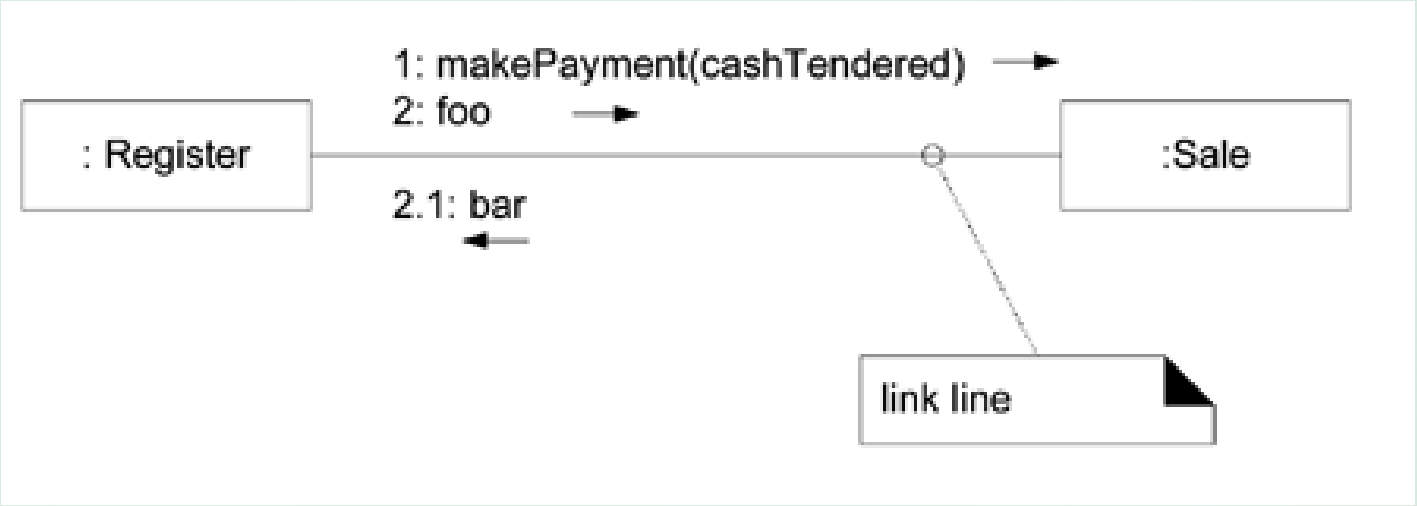


Conti.


polymorphic message
object in role of abstract superclass
:Register
:Payment {abstract}
doX
authorize
stop at this point – don't show any further details for this message
:DebitPayment
:Foo
:CreditPayment
:Bar
authorize
doA
doB
authorize
doX
separate diagrams for each polymorphic concrete case

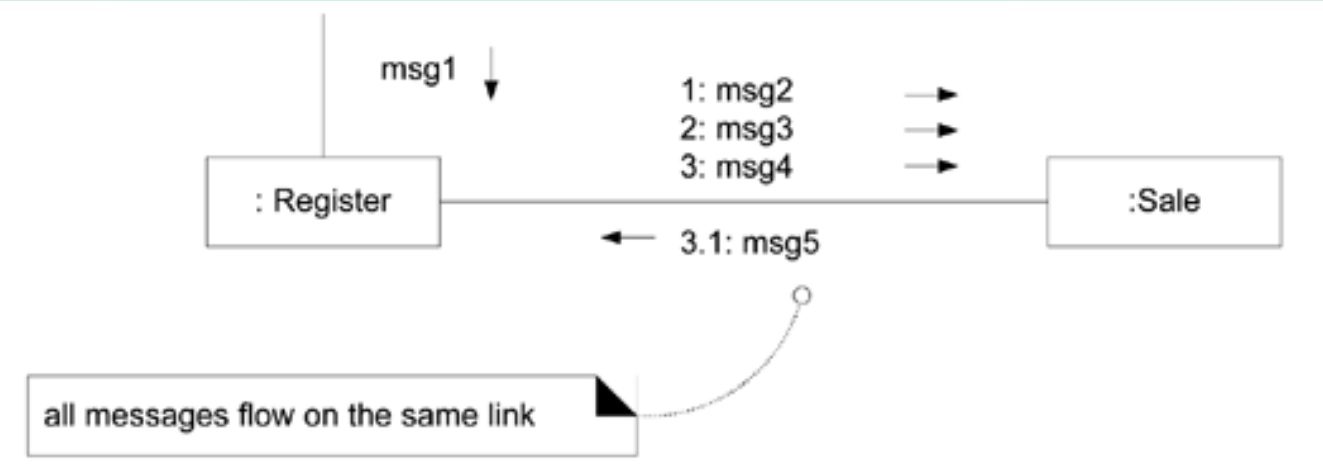
Basic Communication Diagram Notation

- A **link** is a connection path between two objects;
  - it indicates some form of navigation and visibility between the objects is possible
  - More formally, a link is an instance of an association.



Message

- **Messages**
  - Each message between objects is represented with a message expression and small arrow indicating the direction of the message.
  - Many messages may flow along this link.
  - A sequence number is added to show the sequential order of messages in the current thread of control.



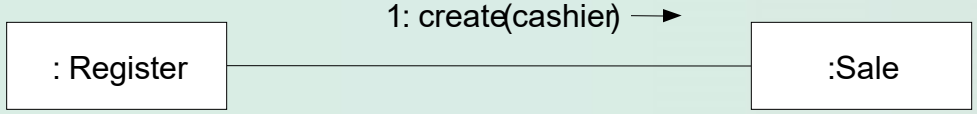
Creation of Instances 1

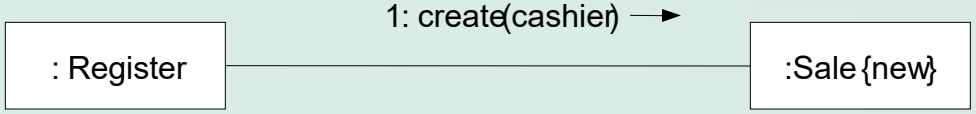
- Any message can be used to create an instance, but the convention in the UML is to use a message named create for this purpose (some use new).
- If another (less obvious) message name is used, the message may be annotated with a UML stereotype, like so: «create».
- The create message may include parameters, indicating the passing of initial values. This indicates, for example, a constructor call with parameters in Java.
- Furthermore, the UML tagged value {new} may optionally be added to the lifeline box to highlight the creation.
- Tagged values are a flexible extension mechanism in the UML to add semantically meaningful information to a UML element.

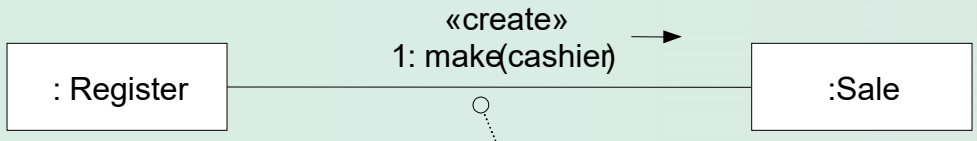
Creation of Instances 2

Three ways to show creation in a communication diagram

create message, with optional initializing parameters. This will normally be interpreted as a constructor call





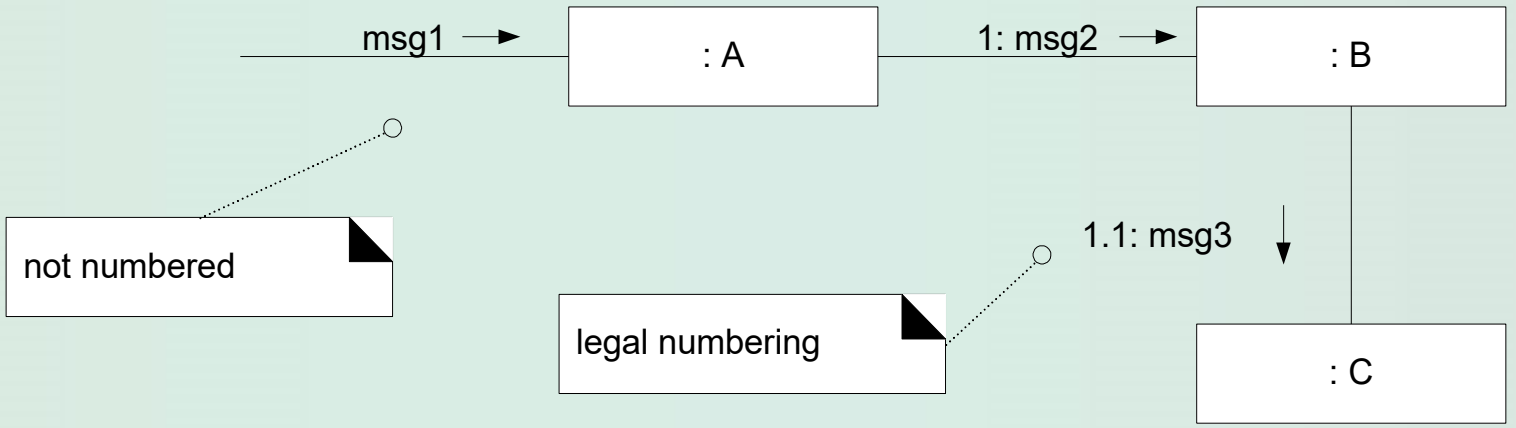


if an unobvious creation message name is used, the message may be stereotyped for clarity

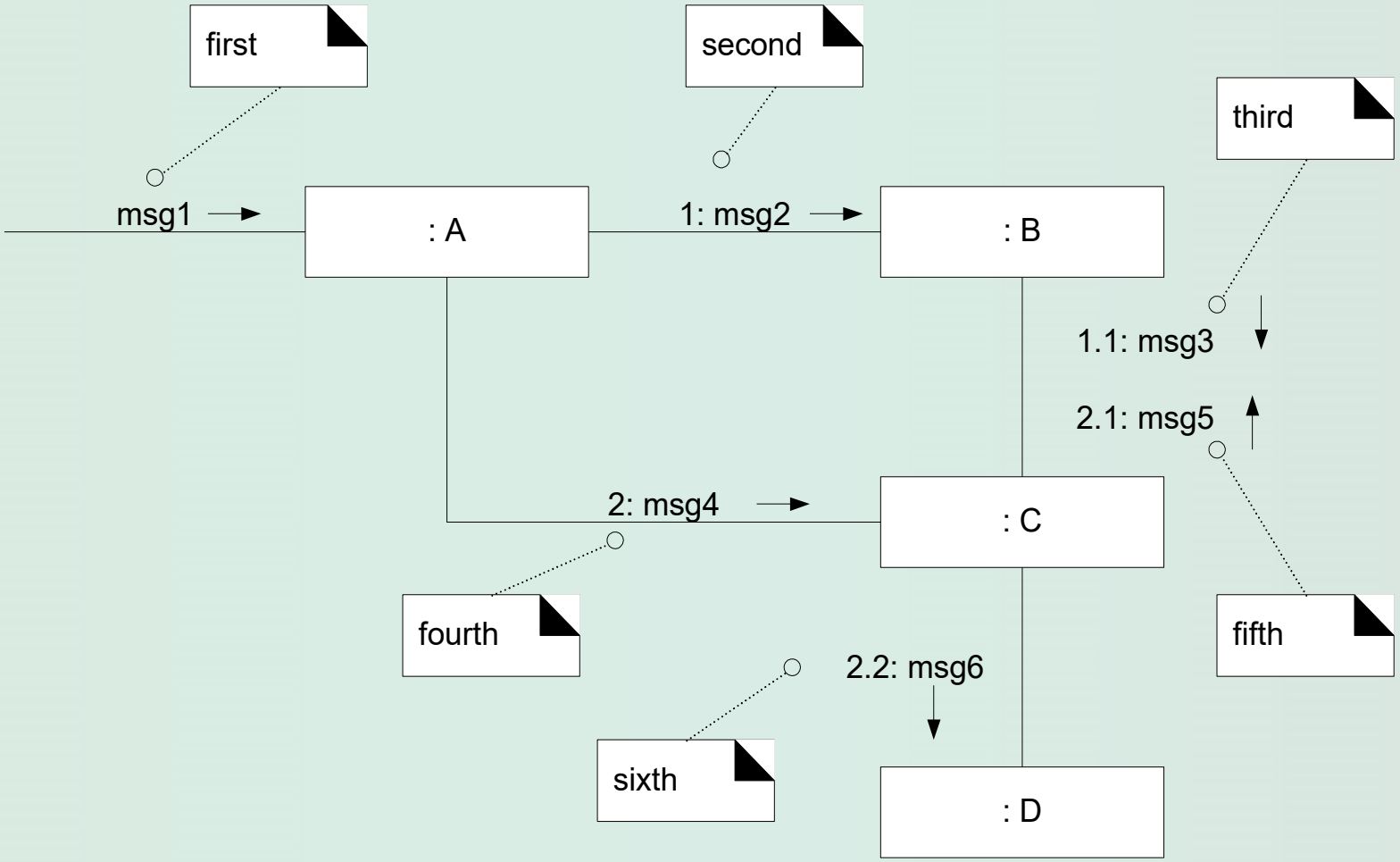
Message Number Sequencing 1

- The order of messages is illustrated with sequence numbers, The numbering scheme is:
  - The first message is not numbered. Thus, msg1 is unnumbered
  - Actually, a starting number is legal, but it makes all subsequent numbering more awkward, creating another level of number-nesting deeper than otherwise necessary.
  - The order and nesting of subsequent messages is shown with a legal numbering scheme in which nested messages have a number appended to them.
  - You denote nesting by pre-pending the incoming message number to the outgoing message number

Message Number Sequencing 2

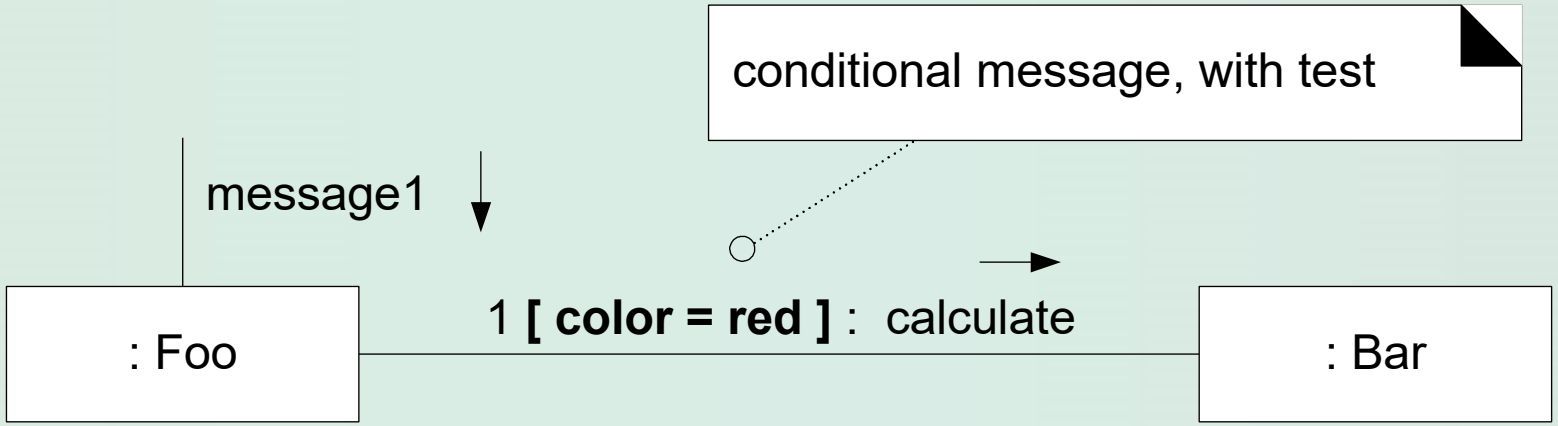


Message Number Sequencing 3

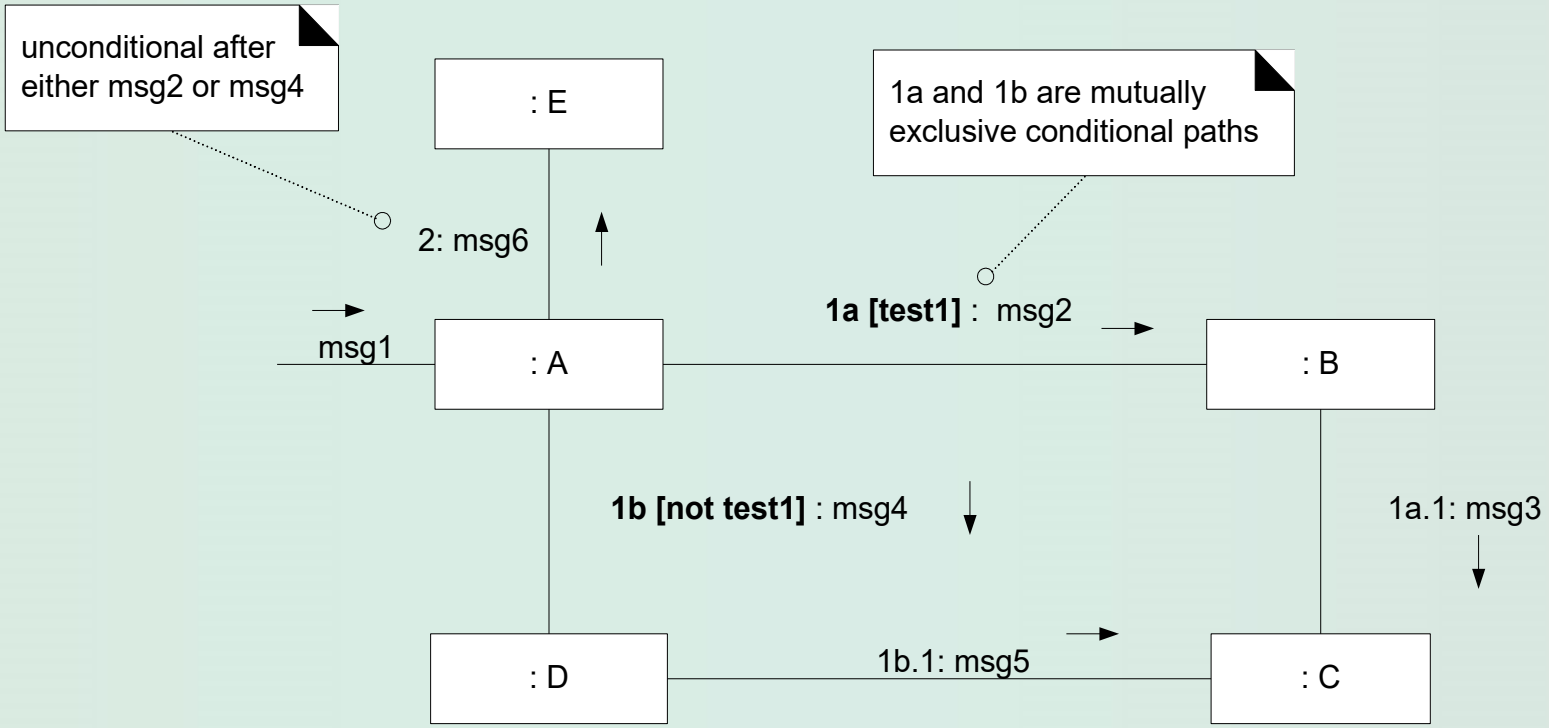


Conditional Messages

- A conditional message is shown by following a sequence number with a conditional clause in square brackets, similar to an iteration clause.
- The message is only sent if the clause evaluates to true.



Mutually Exclusive Conditional Paths 1

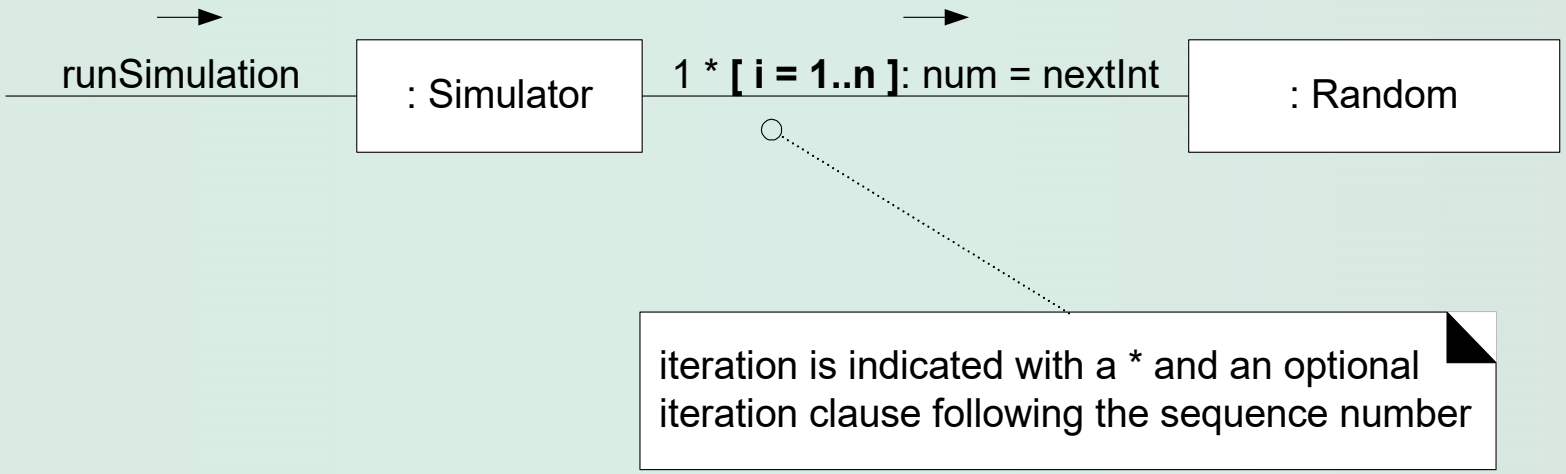


Mutually Exclusive Conditional Paths 2

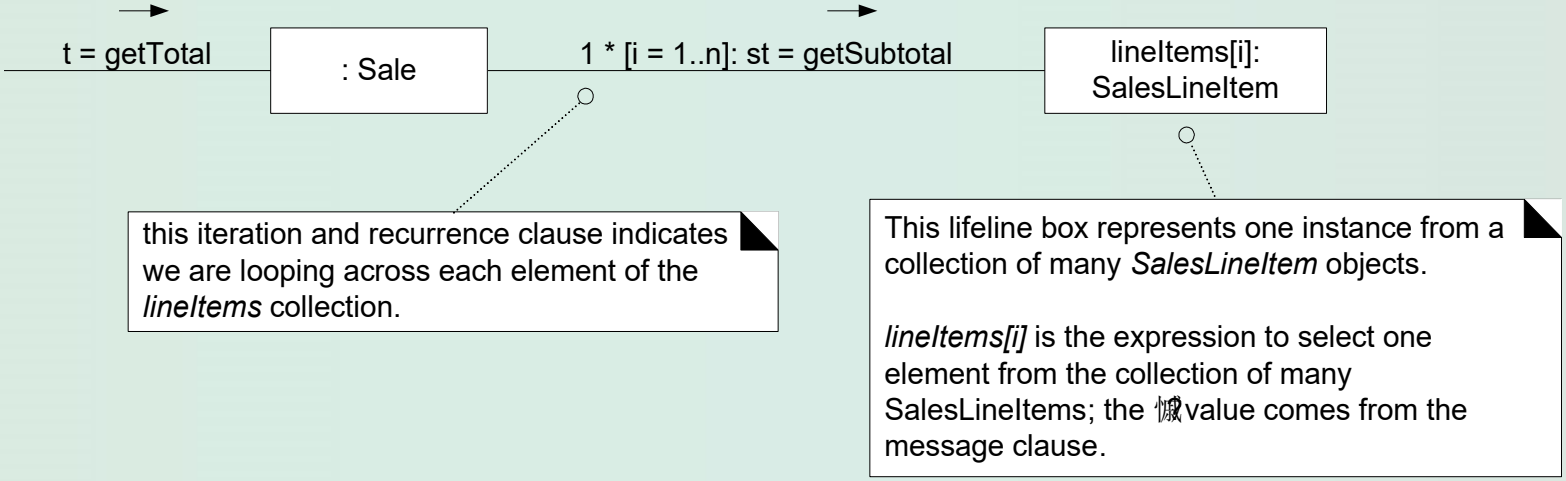
- The example illustrates the sequence numbers with mutually exclusive conditional paths
- In this case we must modify the sequence expressions with a conditional path letter. The first letter used is a by convention. Either 1a or 1b could execute after msg1.
- Both are sequence number 1 since either could be the first internal message.
- Note that subsequent nested messages are still consistently prepended with their outer message sequence. Thus 1b.1 is nested message within 1b.

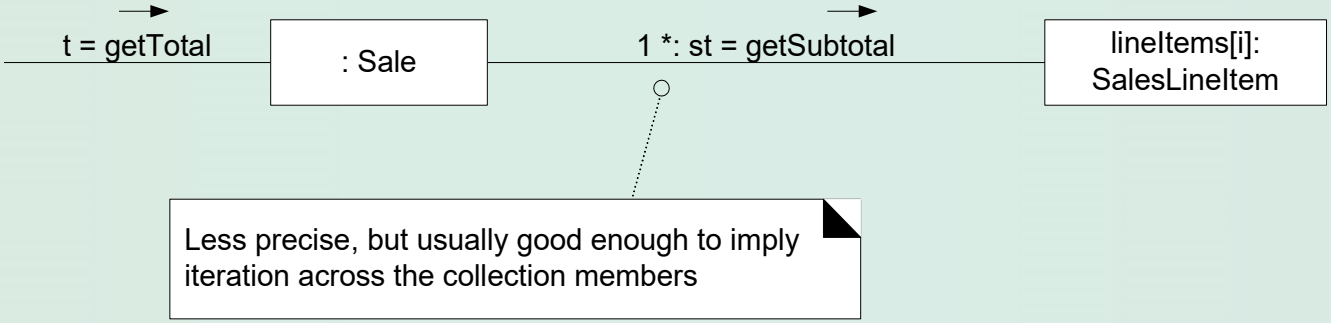
Iteration or Looping

- If the details of the iteration clause are not important to the modeler, a simple * can be used.



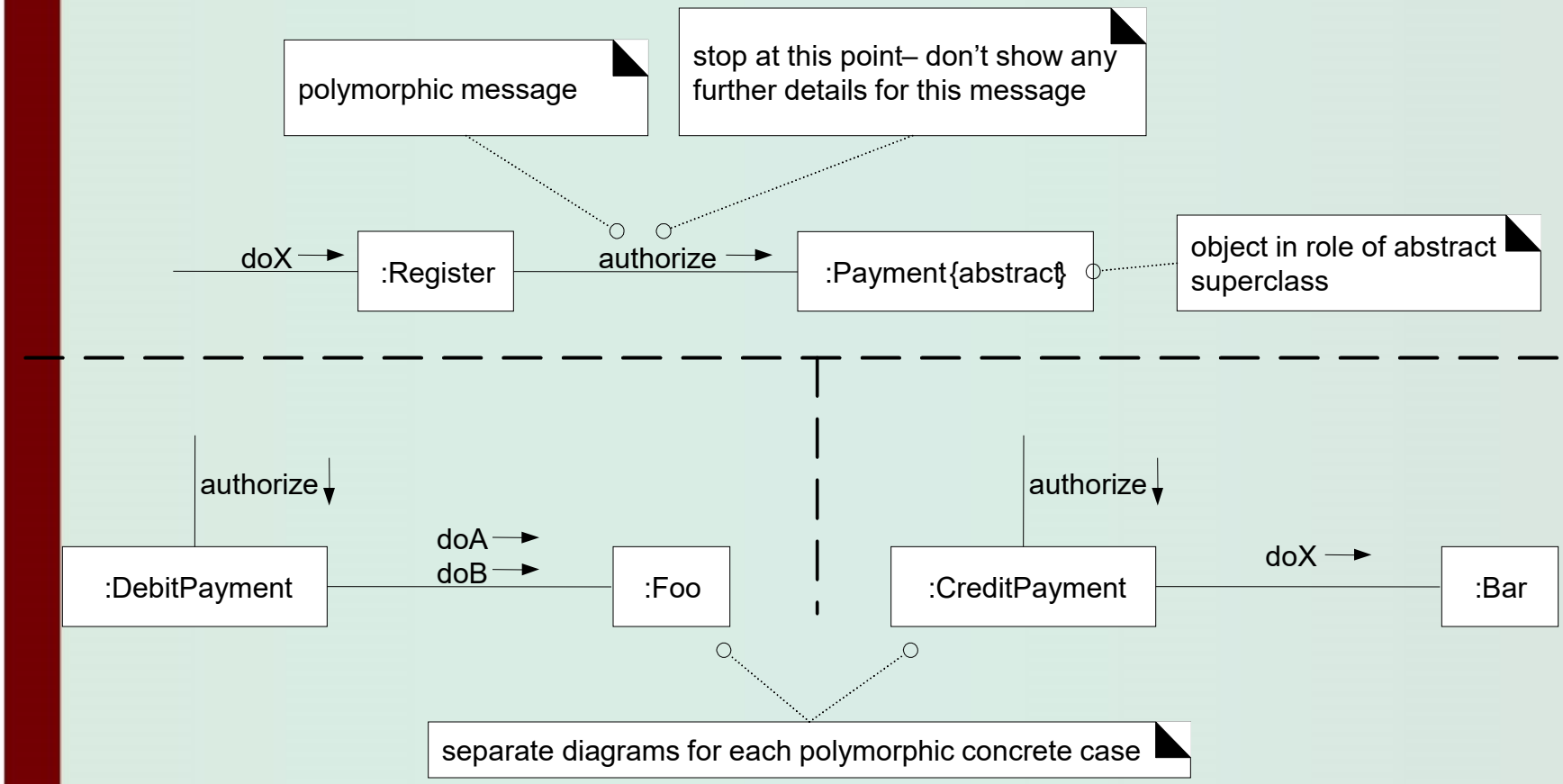
Iteration Over a Collection



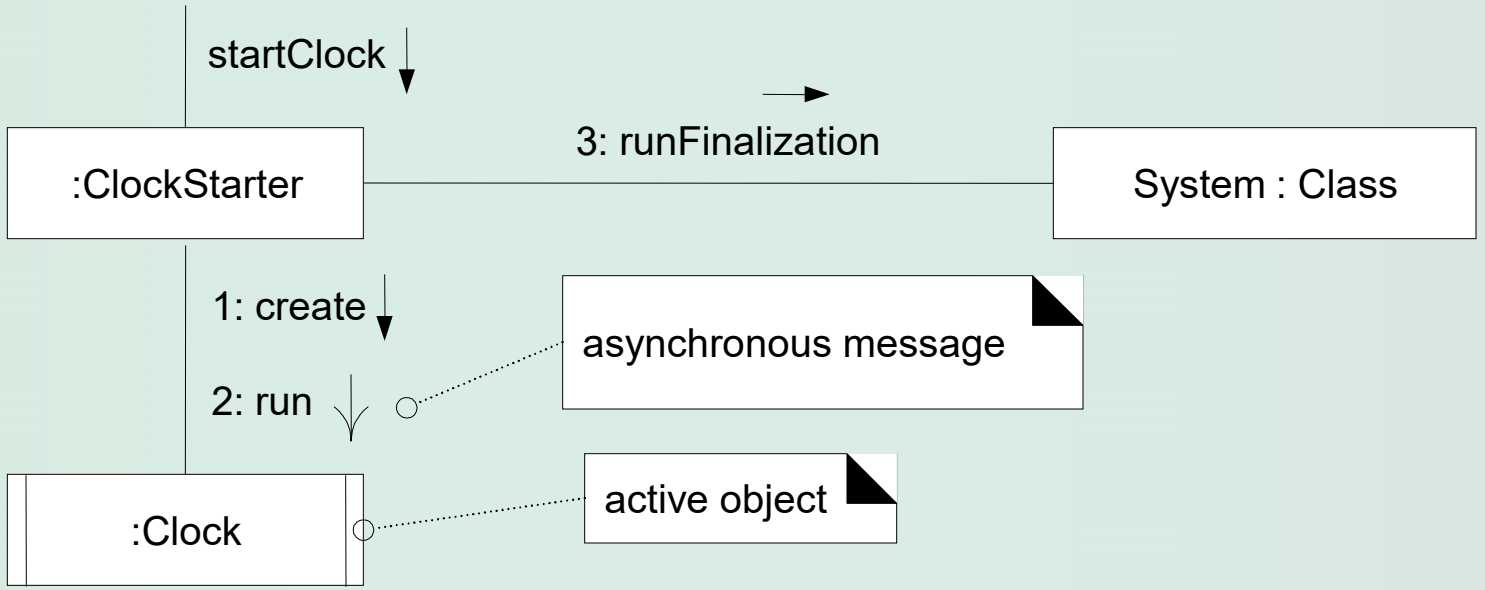


Messages to a Classes to Invoke Static Methods

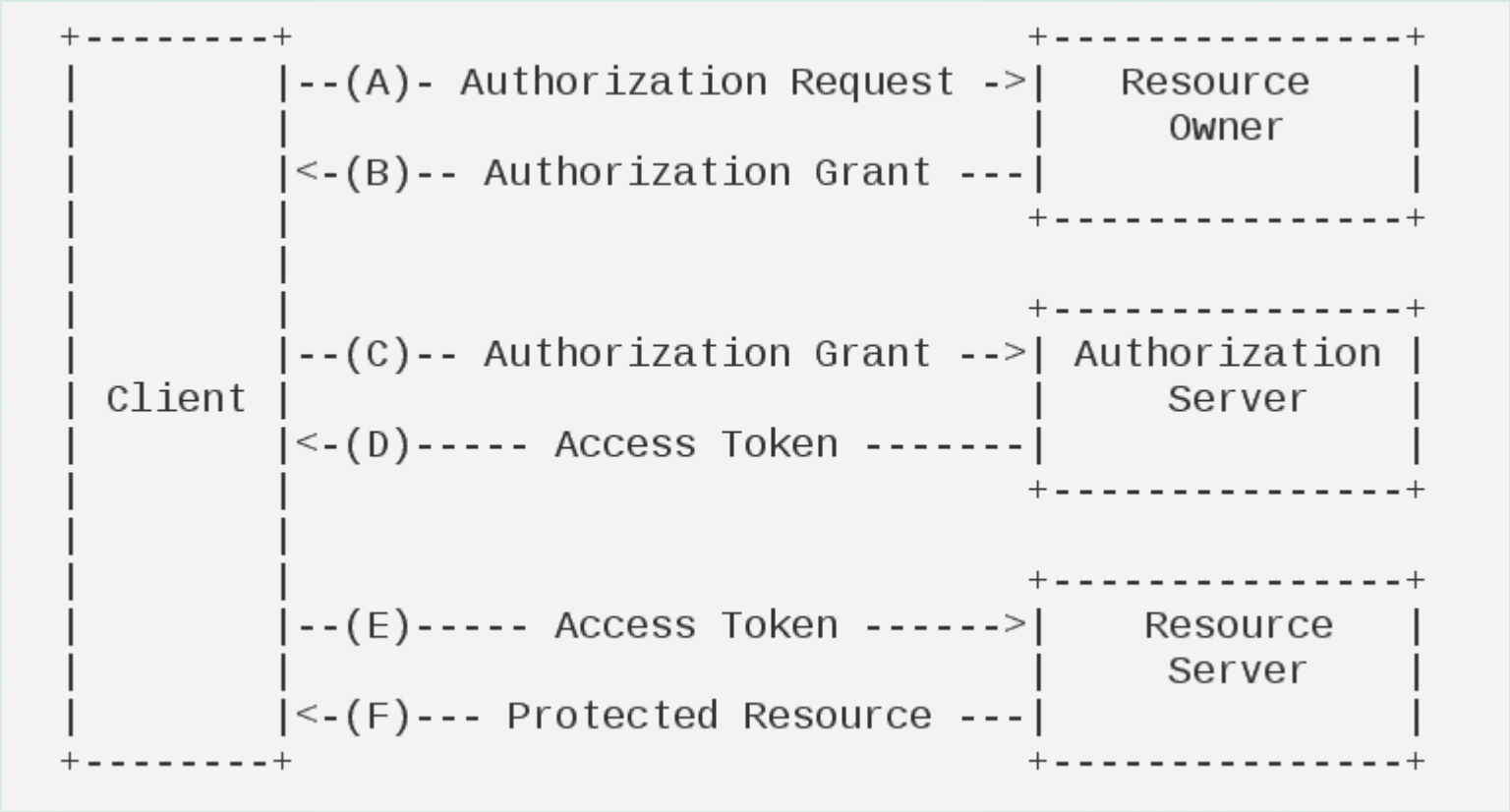
Polymorphic Messages and Cases



Asynchronous and Synchronous Calls

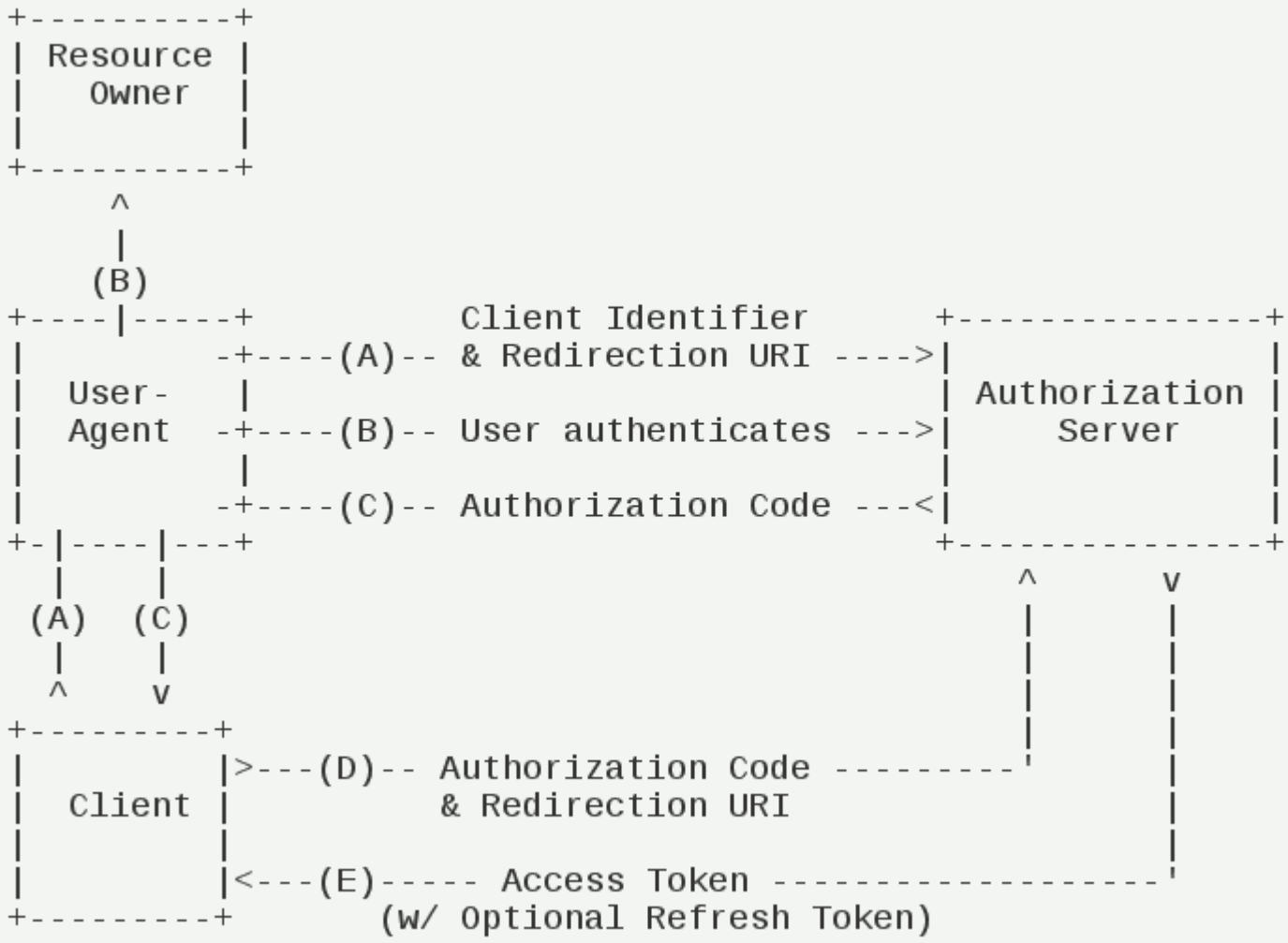


OAuth 2.0 与交互图（1）



http://www.ruanyifeng.com/blog/2014/05/oauth_2_0.html

OAuth 2.0 与交互图（2）



OAuth 2.0 与交互图（3）