Michael Weintraub
And
Frank Tip

SYSTEM AND SOFTWARE DESIGN USING THE UNIFIED MODELING LANGUAGE (UML)

UNIT OBJECTIVE

- Gain perspective on how to think about designing a system
- Introduce a graphical way to describe systems
  - UML

Thanks go to Martin Schedlbauer and to Andreas Zeller for allowing incorporation of their materials on UML

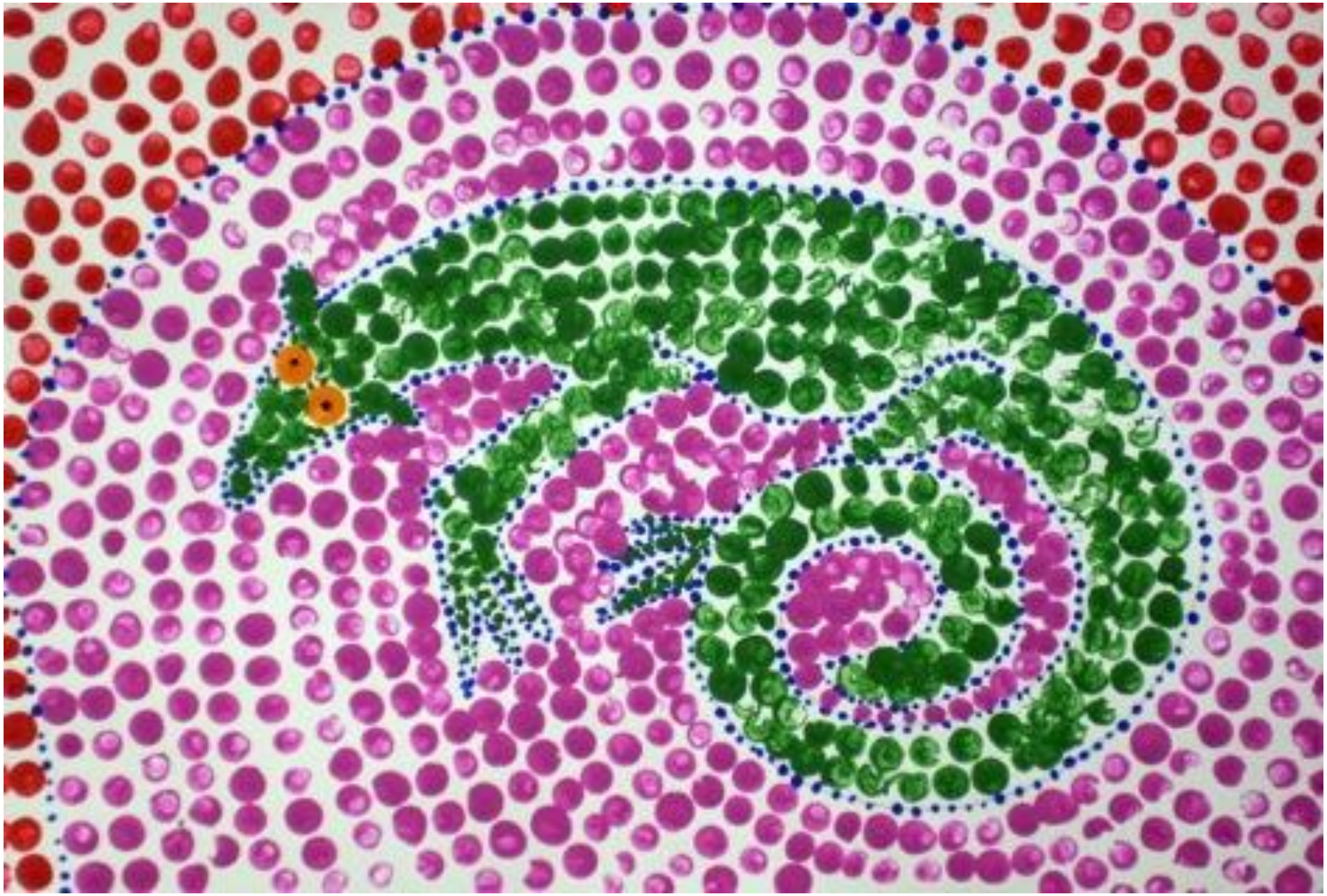
WHY MODEL A SYSTEM?

Helps clarify the requirements

Identifies gaps

Useful tool for understanding how the details really fit in or fit together

A PICTURE IS WORTH A THOUSAND WORDS



UNIFIED MODELING LANGUAGE

UML is a general-purpose visual modeling language developed by an industry consortium in 1997.

Presently, *UML* is in version 2.2 and is controlled by the Object Management Group (OMG).

UML is based on multiple prior visual modeling languages, most notably the Booch Notation, OMT, and OOSE.

UML IS COMPLICATED

- Class
- Component
- Object
- Profile
- Composite Structure
- Deployment
- Package

Static

Structure Diagrams

- Use Case
- Activity
- State
- Sequence
- Communication
- Interaction Overview
- Timing

Dynamic

Behavior Diagrams

UML IS COMPLICATED

- Class
- Component
- Object
- Profile
- Composite Structure
- Deployment
- Package

Static

Structure Diagrams

- Use Case
- Activity
- State
- Sequence
- Communication
- Interaction Overview
- Timing

Dynamic

Behavior Diagrams

Use What You Need. You Probably Don’t Need Everything.

WAIT, WHY CAN'T WE JUST START CODING?

Challenges

- Need to understand what the system does and how it is structured
- Especially important for large/complex systems to get a handle on the complexity

What UML provides

- Useful for visualizing a system
  - 1 picture = 1000 words
- Specifies the structure and/or behavior of a system
- Provides guidelines for constructing an implementation
- Documents the important design decisions
- Facilitates communication between developers and with clients
  - Common language for expressing design elements that is both technical and non-computer technical accessible
- Facilitates reverse engineering: reconstruct a model from an existing implementation
  - Often to re-implement in another language

THERE ARE MANY WAYS TO DESCRIBE A SYSTEM

1. External
   - The system context or environment
2. Interaction
   - How the system interacts with its environment, users, or components
3. Structural
   - The system's organization or data
4. Behavioral
   - The system's dynamic behavior and how it responds to events

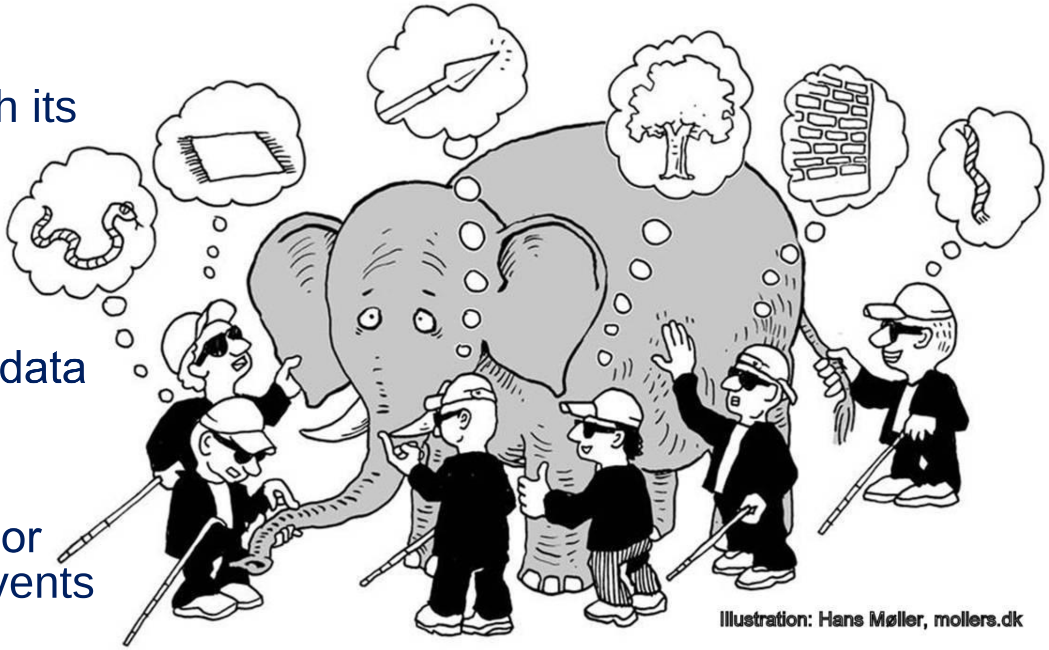


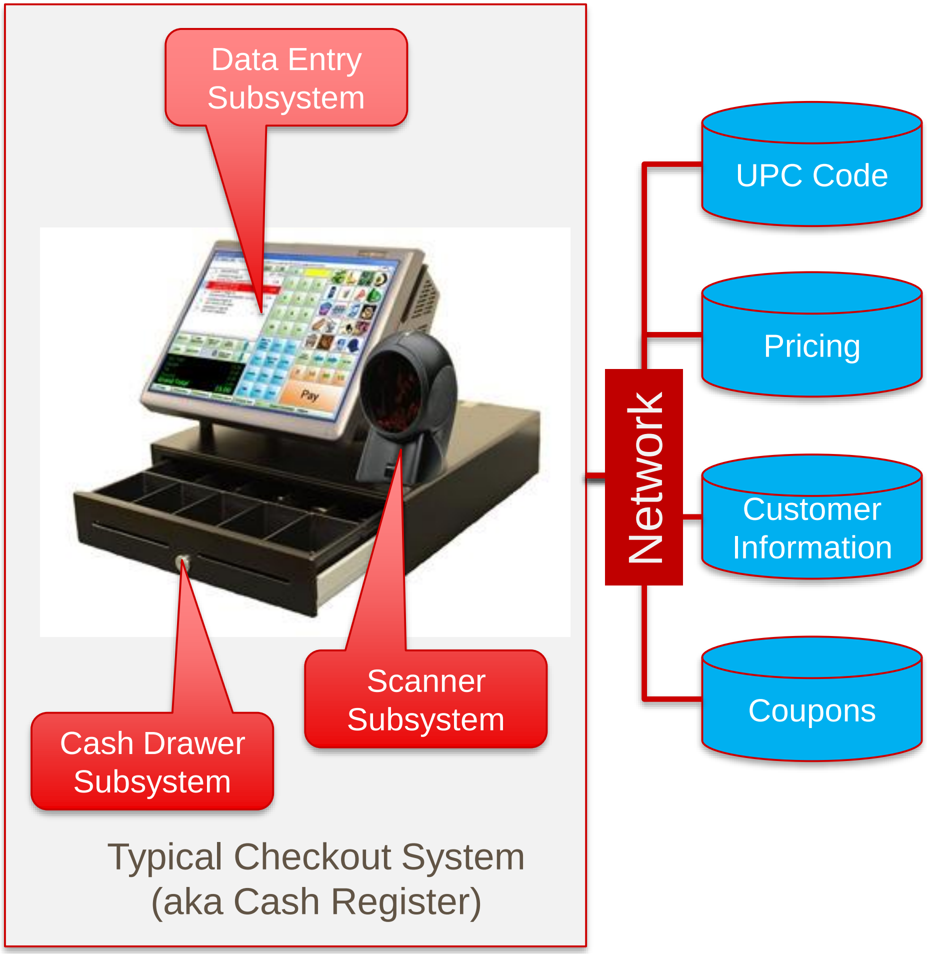
Illustration: Hans Møller, mollers.dk

THE EXTERNAL PERSPECTIVE

Places the system in context

Good for identifying
what is part of the system
and
what is not part of the system

The boundaries may not always be clear



Typical Checkout System (aka Cash Register)

THE INTERACTION PERSPECTIVE

How the system interacts with its environment, users, or components

1. Use Case Diagrams
   - How actors interact with a system
     - *Especially useful for requirements gathering and initial work with clients*
2. Sequence Diagrams
   - How entities operate with one anothe in specific order

Other diagram types are available

LET'S START WITH A SIMPLE EXAMPLE: ORDERING COFFEE AT A COFFEE SHOP

1. (start) Customer approaches the counter and tells the cashier what she wants
2. The cashier enters the beverage order into the point-of-sale system (POS)
3. The cashier asks for the customer's name and notes it on the order
4. The customer pays for the order
5. The cashier records the payment
6. The cashier communicates the order details to the barista
7. The barista prepares the beverage order
8. Upon completion of the order, the barista places the beverage on the pick-up counter and calls the customer's name
9. The customer picks up the beverage and walks away (end).

THE STORY IS RICH IN INFORMATION

1. (start) Customer approaches the counter and tells the cashier what she wants
2. The cashier enters the beverage order into the point-of-sale system (POS)
3. The cashier asks for the customer’s name and notes it on the order
4. The customer pays for the order
5. The cashier records the payment
6. The cashier communicates the order details to the barista
7. The barista prepares the beverage order
8. Upon completion of the order, the barista places the beverage on the pick-up counter and calls the customer’s name
9. The customer picks up the beverage and walks away.(end)

THE STORY IS RICH IN INFORMATION

1. (start) Customer approaches the counter and tells the cashier what she wants
2. The cashier enters the beverage order into the point-of-sale system (POS)
3. The cashier asks for the customer’s name and notes it on the order
4. The customer pays for the order
5. The cashier records the payment
6. The cashier communicates the order details to the barista
7. The barista prepares the beverage order
8. Upon completion of the order, the barista places the beverage on the pick-up counter and calls the customer’s name
9. The customer picks up the beverage and walks away.(end)

Actors and Objects

THE STORY IS RICH IN INFORMATION

1. (start) Customer approaches the counter and tells the cashier what she wants
2. The cashier enters the beverage order into the point-of-sale system (POS)
3. The cashier asks for the customer's name and notes it on the order
4. The customer pays for the order
5. The cashier records the payment
6. The cashier communicates the order details to the barista
7. The barista prepares the beverage order
8. Upon completion of the order, the barista places the beverage on the pick-up counter and calls the customer's name
9. The customer picks up the beverage and walks away.(end)

Systems

Actors and Objects

THE STORY IS RICH IN INFORMATION

1. (start) Customer approaches the counter and tells the cashier what she wants
2. The cashier enters the beverage order into the point-of-sale system (POS)
3. The cashier asks for the customer's name and notes it on the order
4. The customer pays for the order
5. The cashier records the payment
6. The cashier communicates the order details to the barista
7. The barista prepares the beverage order
8. Upon completion of the order, the barista places the beverage on the pick-up counter and calls the customer's name
9. The customer picks up the beverage and walks away.(end)

Actions

Actors and Objects

Systems

THE STORY IS RICH IN INFORMATION

1. (start) Customer approaches the counter and tells the cashier what she wants
2. The cashier enters the beverage order into the point-of-sale system (POS)
3. The cashier asks for the customer's name and notes it on the order
4. The customer pays for the order
5. The cashier records the payment
6. The cashier communicates the order details to the barista
7. The barista prepares the beverage order
8. Upon completion of the order, the barista places the beverage on the pick-up counter and calls the customer's name
9. The customer picks up the beverage and walks away.(end)

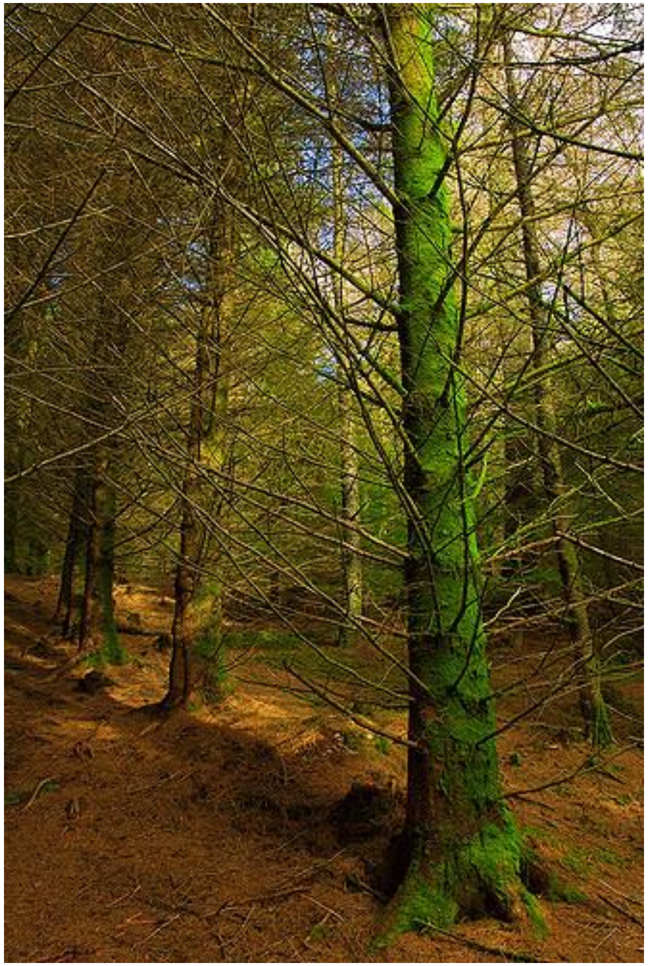
Events

Actors and Objects

Systems

Actions

NEED: REPRESENT SYSTEMS, ACTORS AND OBJECTS, ACTIONS, AND EVENTS AND HOW THEY COME TOGETHER



USE CASE DIAGRAMS

- How actors interact with a system
  - An actor is a prospective user
    - *It can also be external systems*

  - A scenario is a sequence of steps between an actor and the system
    - *Lists the steps in each successful and unsuccessful scenario that make up the interaction*
    - *Usually written as prose*

  - A use case is a set of scenarios with a common user goal
    - *One can distinguish business use cases from system use cases*

      Business process design versus system process design

- Design hint: a use case shows what a system does, not how it does it
  - ➢ keep descriptions short, clear, and precise
  - ➢ separate main flow of events from alternate and exceptional flows

- ***Especially useful for requirements gathering*** **and** ***initial work with clients***

USE CASE$_0$: ORDERING AT A COFFEE SHOP FROM THE CASHIER'S PERSPECTIVE

1. (start) Customer approaches the counter, **cashier** hears what customer orders
2. The **cashier** enters the customer order into the point-of-sale system (POS)
3. The **cashier** asks customer for a name and notes name on the customer order
4. The **cashier** gets the customer's money to cover the order
5. The **cashier** records the payment
6. The **cashier** communicates the order's details to the barista
7. (end)

Guide: **actor** action objects-of-action

USE CASE$_0$: NOW AN ALTERNATIVE

1. (start) Customer approaches the counter, **cashier** hears what customer orders
    a. If the store is presently out of the materials needed for the order, **cashier** tells customer "we are out of X" and suggests a near alternative
    b. **cashier** hears what **customer** orders instead
2. The **cashier** enters the customer order into the point-of-sale system (POS)
3. The **cashier** asks customer for a name and notes name on the customer order
4. The **cashier** gets the customer's money to cover the order
5. The **cashier** records the payment
6. The **cashier** communicates the order's details to the barista
7. (end)

Guide: **actor** action objects-of-action

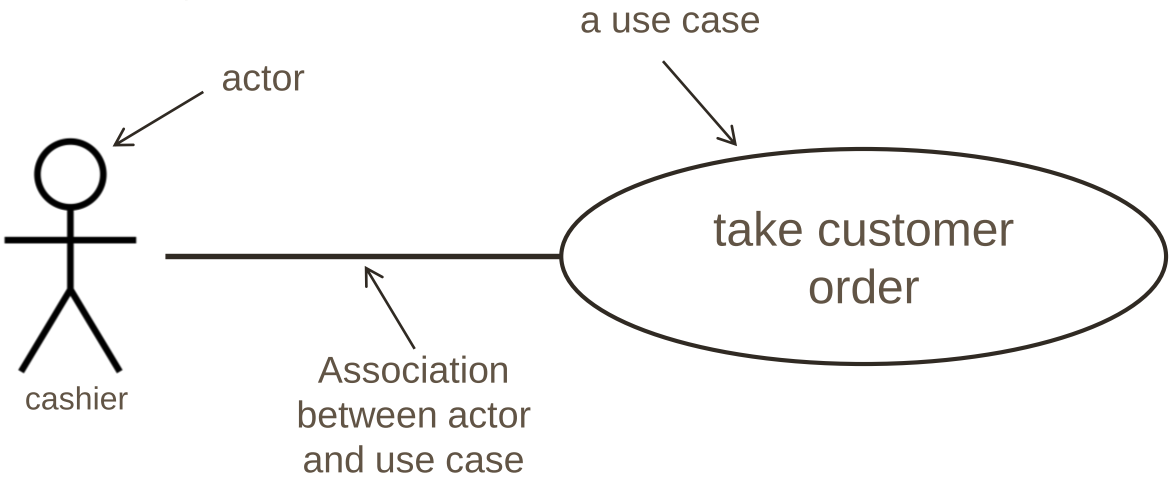
USE CASE$_0$: ORDER FROM THE WEB

1. (start) **Customer** start app on his phone and *logs in*.
2. **Customer** picks preferred store.
3. **Customer** enters coffee choice.
4. **App** asks *if “he would like anything else.”*
5. **Customer** selects “checkout.”
6. **App** asks for payment.
7. **Customer** enters credit card number.
8. **App** validates the order.
9. Once done, **App** sends the order to the POS machine at preferred store and leaves a confirm message in the customer’s email inbox.
10. The **cashier** communicates the order’s details to the barista
11. (end)

Guide: **actor** action objects-of-action

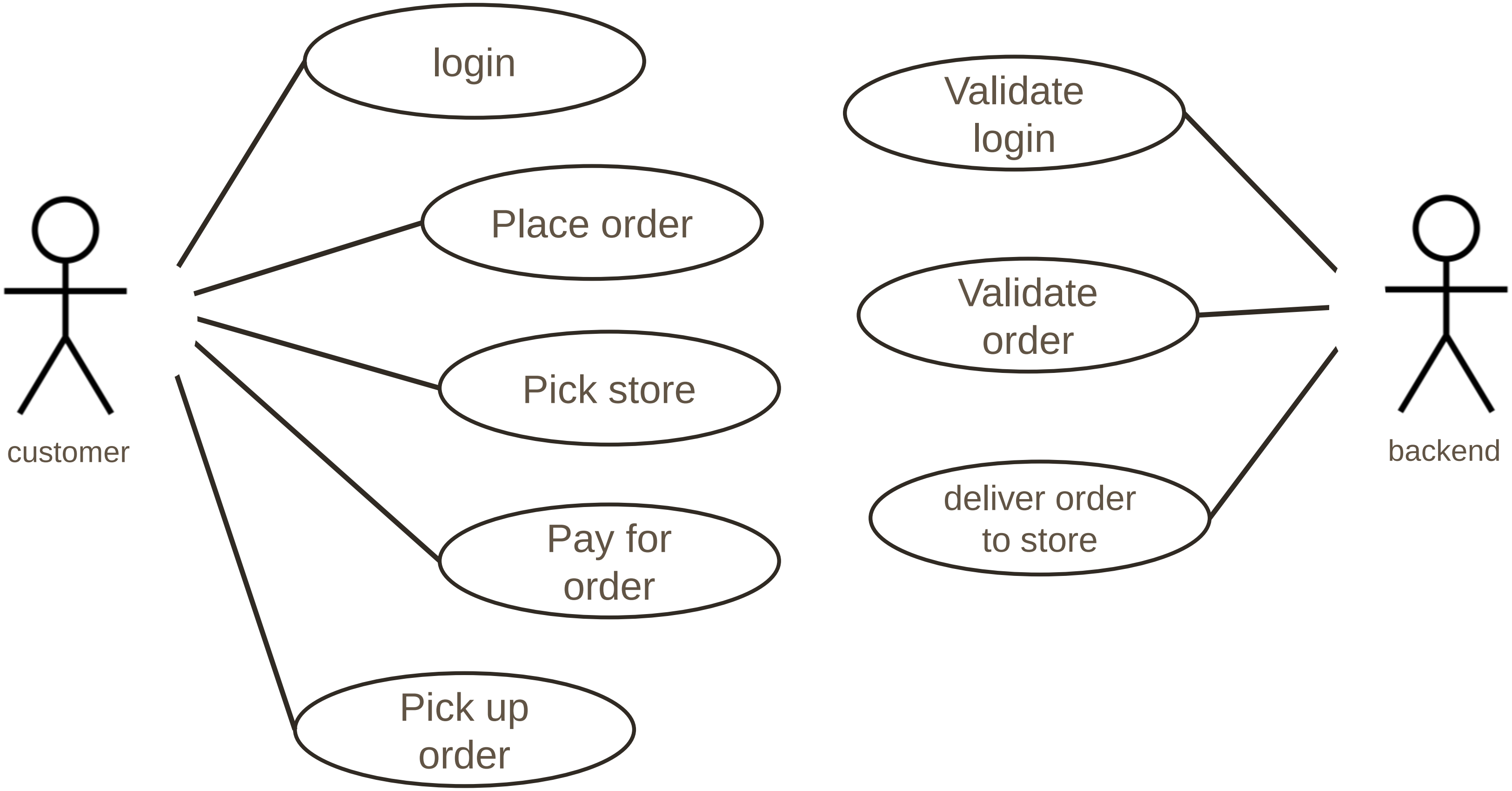
WRITING USE CASE DIAGRAMS IN UML

- Use cases: oval with text inside
- Actors: stick figure
- Dependencies, generalizations, associations



- Actors are really roles played by people. One person may play multiple roles.
    - However, actors may also be another system.
- Actors and use cases each have names.

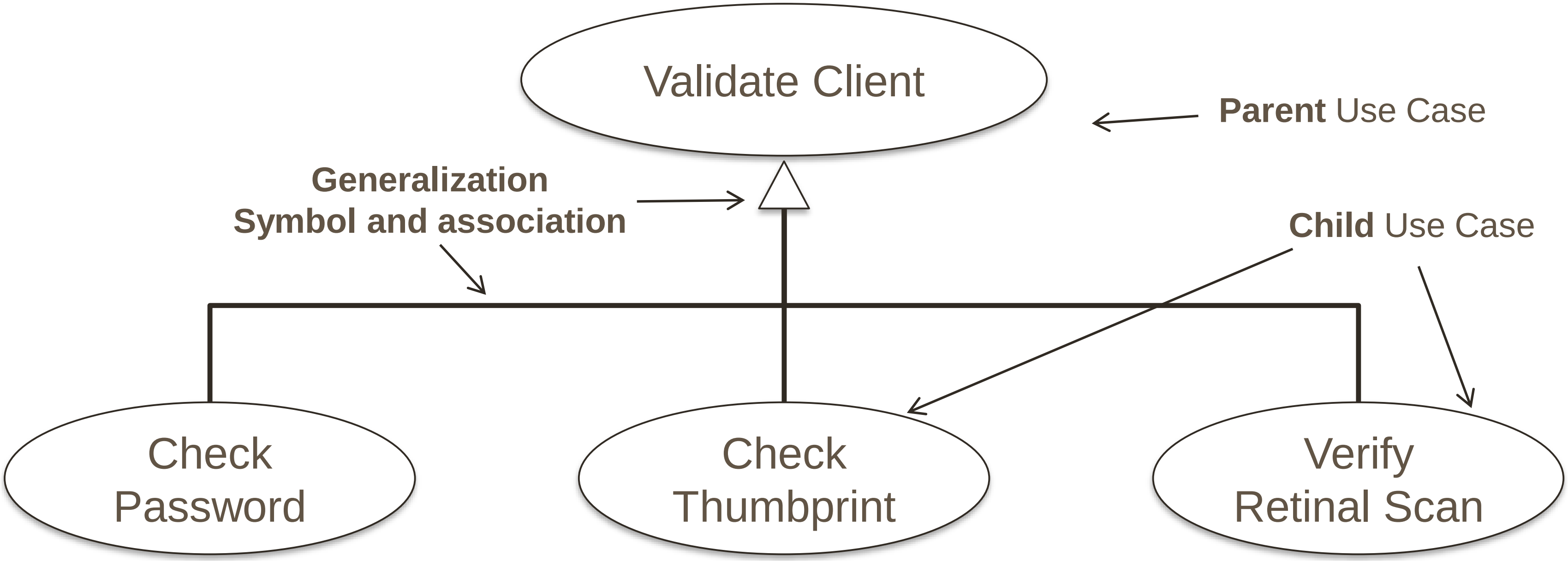
WRITING USE CASE DIAGRAMS IN UML



Use Case$_0$: Ordering coffee from the app

ONE WAY TO REDUCE NOTATIONS

- Use Case Generalization
  - Child use case *inherits behavior and meaning* from parent use case
  - Child may add or override parent behavior
  - Child may be substituted wherever parent occurs



Validate Client

Parent Use Case

Generalization Symbol and association

Child Use Case

Check Password

Check Thumbprint

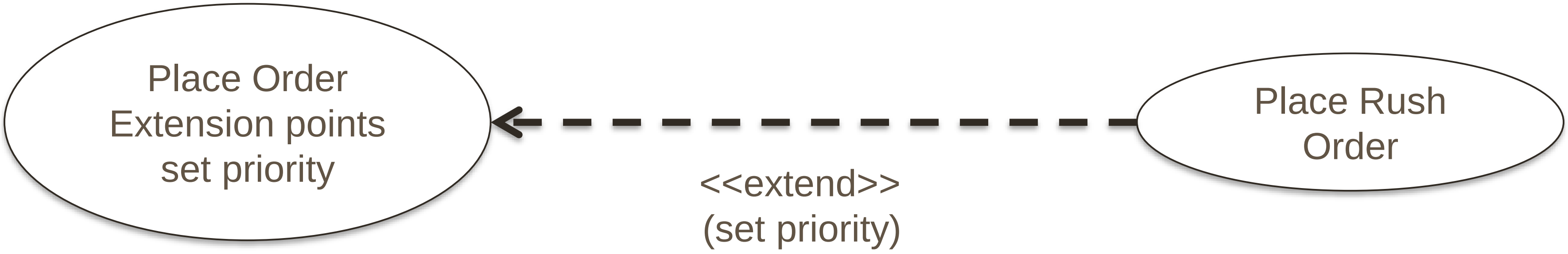
Verify Retinal Scan

EXTENDING USE CASES

- Efficient way to model optional system behavior

- The extending use case may add behavior to the base use case, but:
  - The base use case must declare certain extension points
  - The extending use case may add additional behavior only at those extension points

- **The Extended** use case is meaningful on its own as it is **independent** of the extending use case.



Place Order
Extension points
set priority

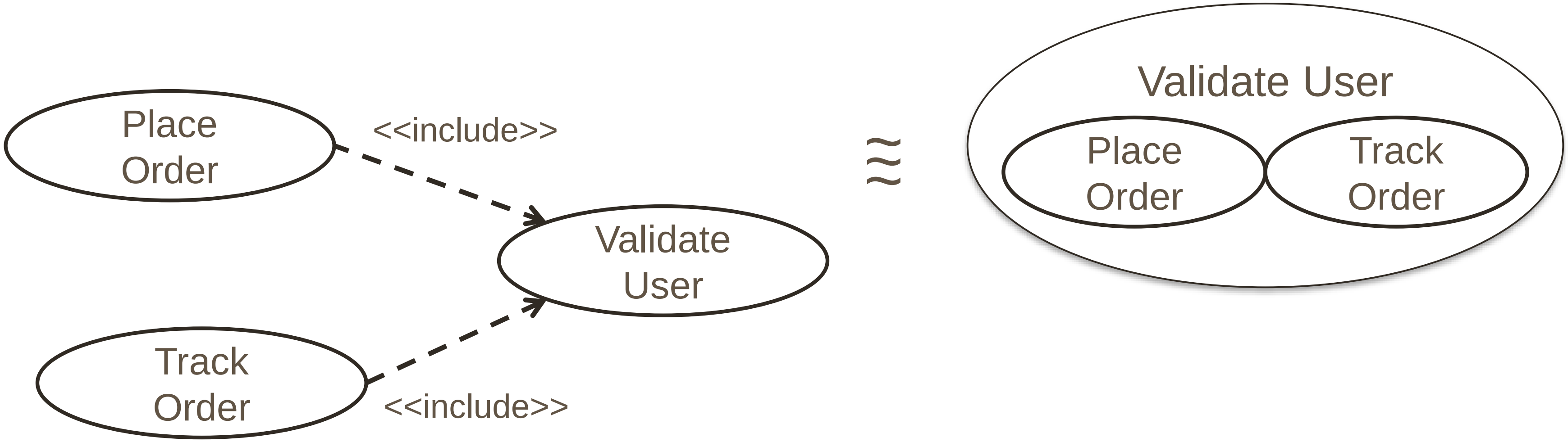
Place Rush Order

<<extend>>
(set priority)

Use Case$_0$: Adding “priority” to Ordering coffee from the app

AVOIDING REPETITIVE DESCRIPTIONS

- Put common event flows into a use case of its own and then **include** it into the behavior of the (base) use case.
- The **include** relationship is used to:
  - simplify large use case by splitting it into several use cases
  - represent common parts of the behaviors of other use cases



Place Order

<<include>>

Validate User

Track Order

<<include>>

≈

Validate User

Place Order

Track Order

GUIDELINES FOR CHOOSING RELATIONSHIPS

1. Use `<<include>>` to avoid repetition when you are repeating yourself in two or more separate use cases

2. Use `generalization` when you are describing a variation on normal behavior, and you wish to describe it casually

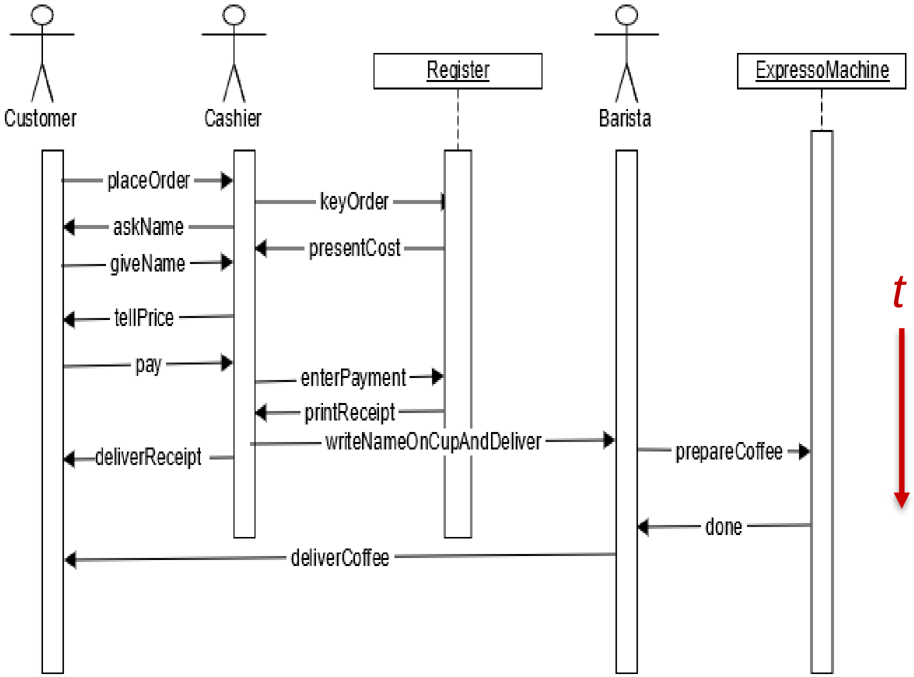
3. Use `<<extend>>` when you are describing a variation on normal behavior and you wish to use the more controlled form, declaring your extension points in the base use case

(taken from Martin Fowler’s UML Distilled)

SEQUENCE DIAGRAMS

- Shows the flow between elements of a system (the messaging *sequence*)
  - Classes (instances of classes)
  - Components
  - Subsystems
  - Actors

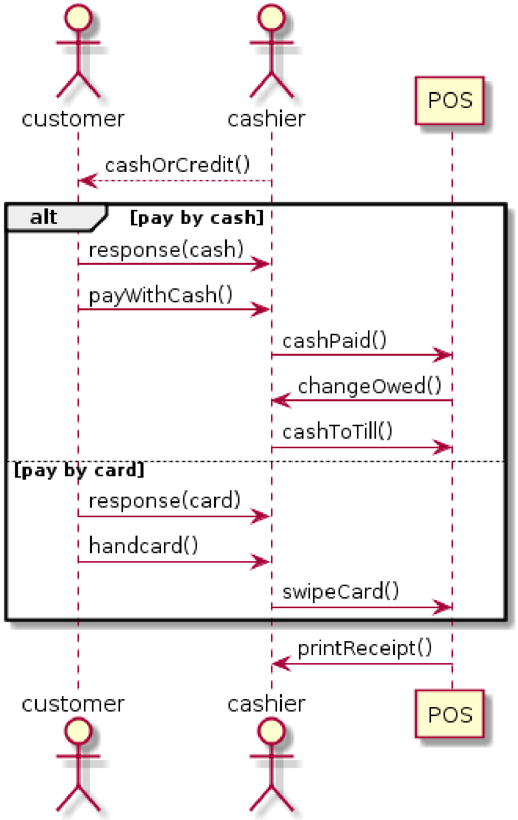
- Time is explicitly shown and flows from top to bottom



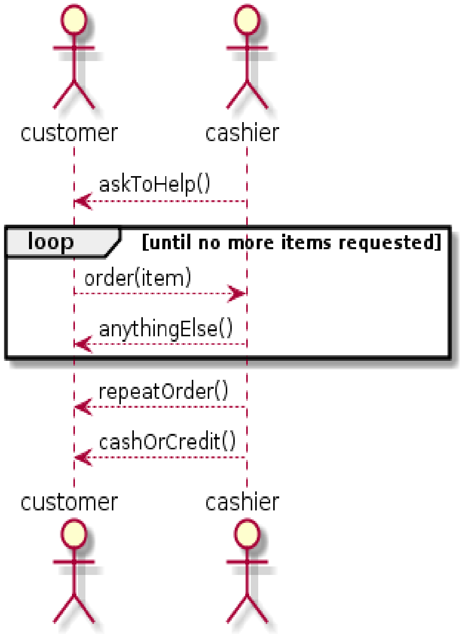
Use Case$_0$

CONTROL FLOWS

Conditional Flow



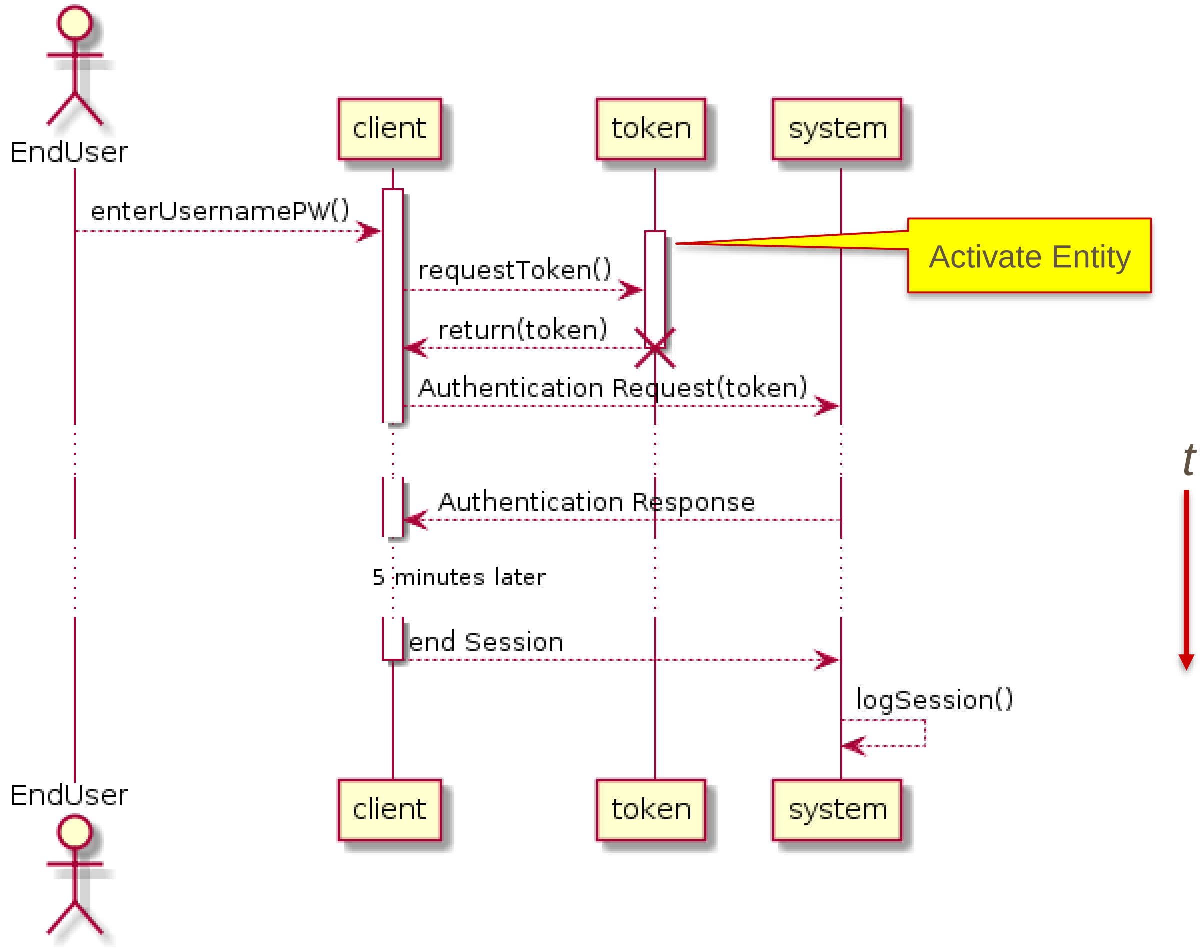
Loops



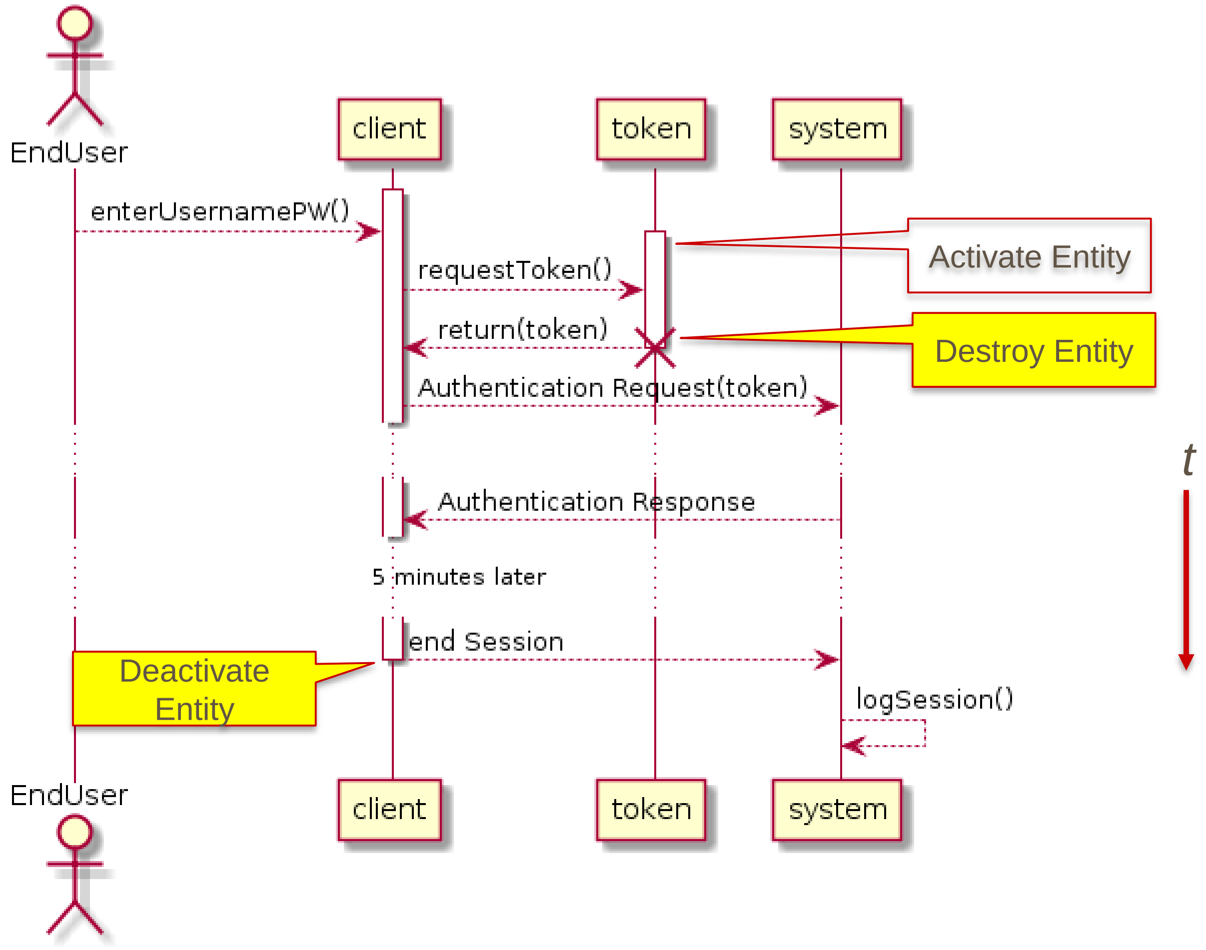
t

Use Case$_0$

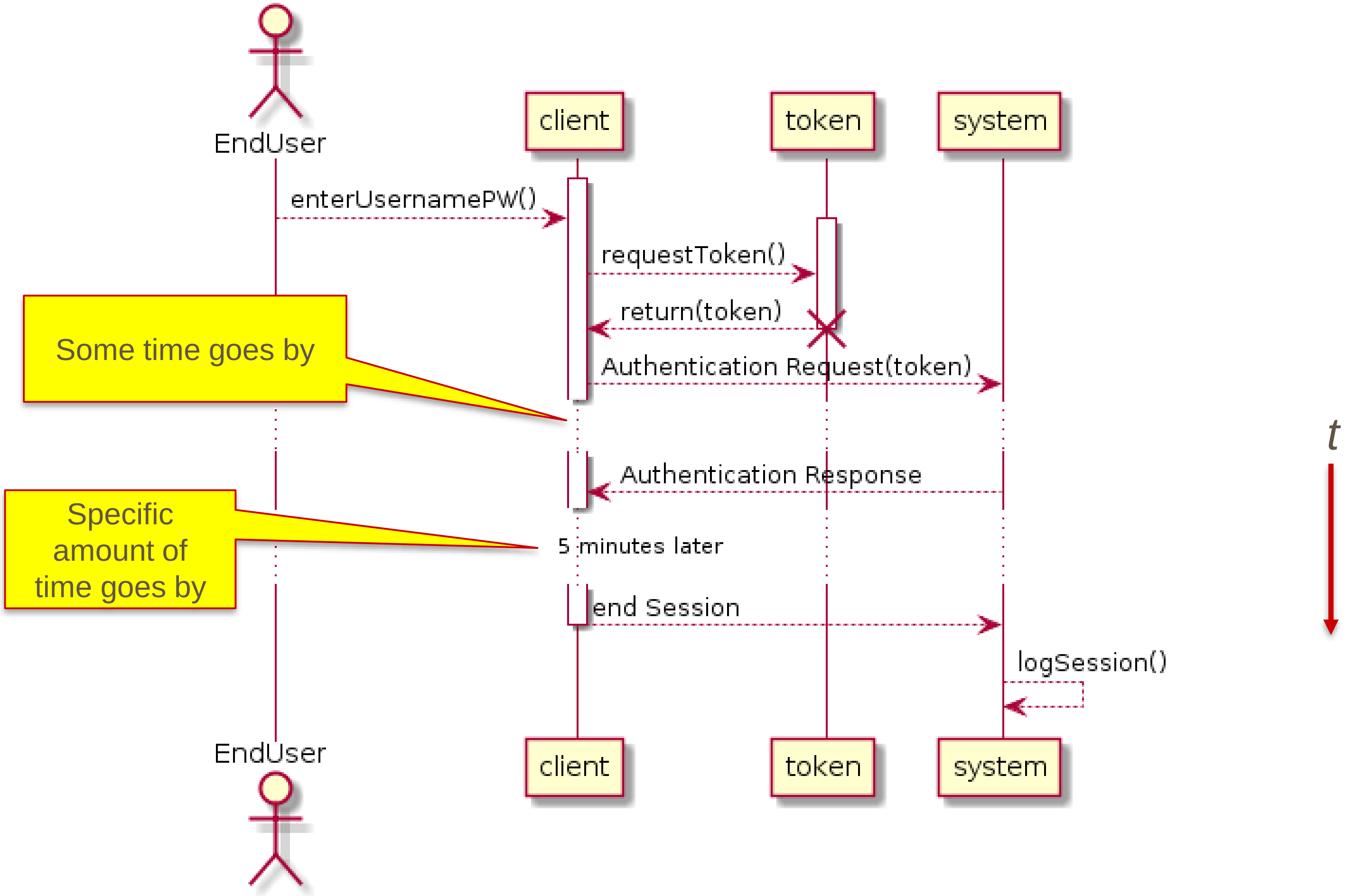
ADDITIONAL (USEFUL) NOTATIONS



ADDITIONAL (USEFUL) NOTATIONS



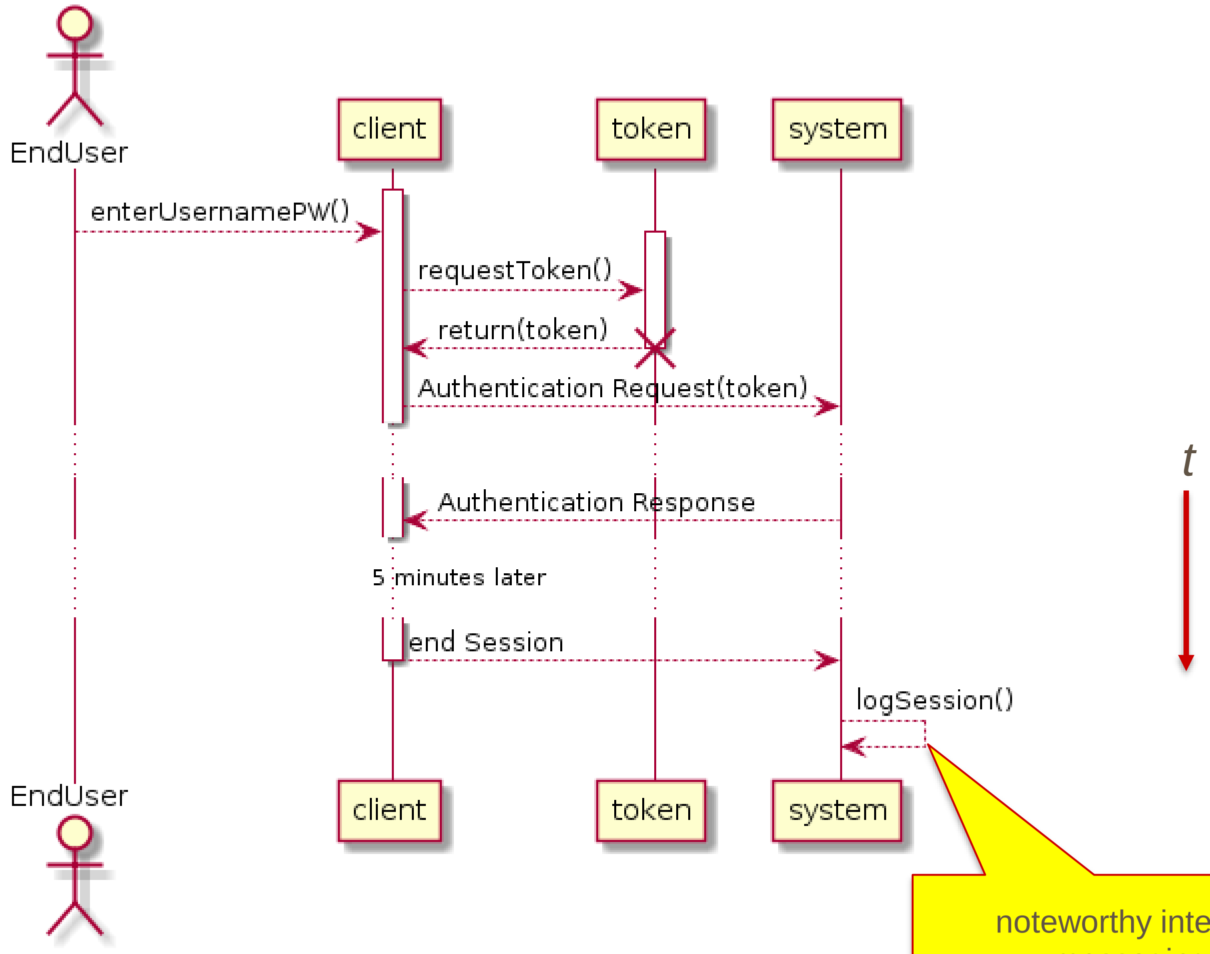
ADDITIONAL (USEFUL) NOTATIONS



Some time goes by

Specific amount of time goes by

ADDITIONAL (USEFUL) NOTATIONS

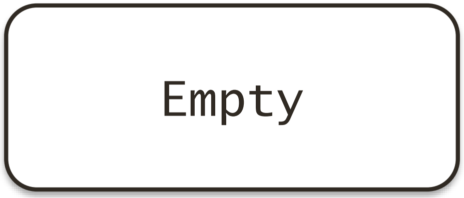


noteworthy internal messaging

SHIFTING GEARS: STATE

- state
  - a condition or situation in the life on an object during which it satisfies some condition, performs some activity, or waits for some event
  - typically described by a set of attribute values

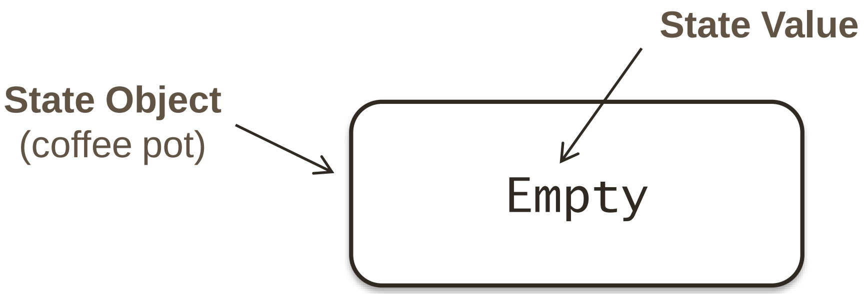
- examples:
  - a coffee pot: state depends on current amount of coffee, temperature, …
  - an order: state can be pending, in processing, fulfilled, cancelled, delivered, ...



SHIFTING GEARS: STATE

- state
  - a condition or situation in the life on an object during which it satisfies some condition, performs some activity, or waits for some event
  - typically described by a set of attribute values

- examples:
  - a coffee pot: state depends on current amount of coffee, temperature, …
  - an order: state can be pending, in processing, fulfilled, cancelled, delivered, ...



State Value

State Object
(coffee pot)

Empty

WHERE THERE ARE STATES, THERE ARE TRANSITIONS

- Events cause states to change
  - state transitions are considered to be atomic (cannot be interrupted)

- state transitions may be labeled
  - Event [Guard] / Action

- an event is a significant happening (a message or signal that is received)

- an action is associated with a transition
  - a process that occurs quickly and is not interruptible

- a guard is a logical condition
  - returns true or false

WHERE THERE ARE STATES, THERE ARE TRANSITIONS

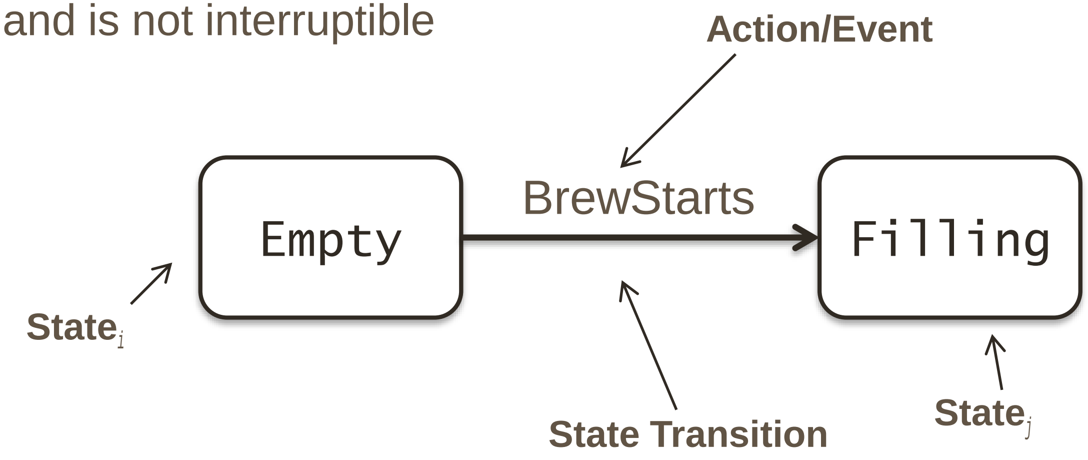
- Events cause states to change
  - state transitions are considered to be atomic (cannot be interrupted)

- state transitions may be labeled
  - Event [Guard] / Action

- an event is a significant happening (a message or signal that is received)

- an action is associated with a transition
  - a process that occurs quickly and is not interruptible

- a guard is a logical condition
  - returns true or false



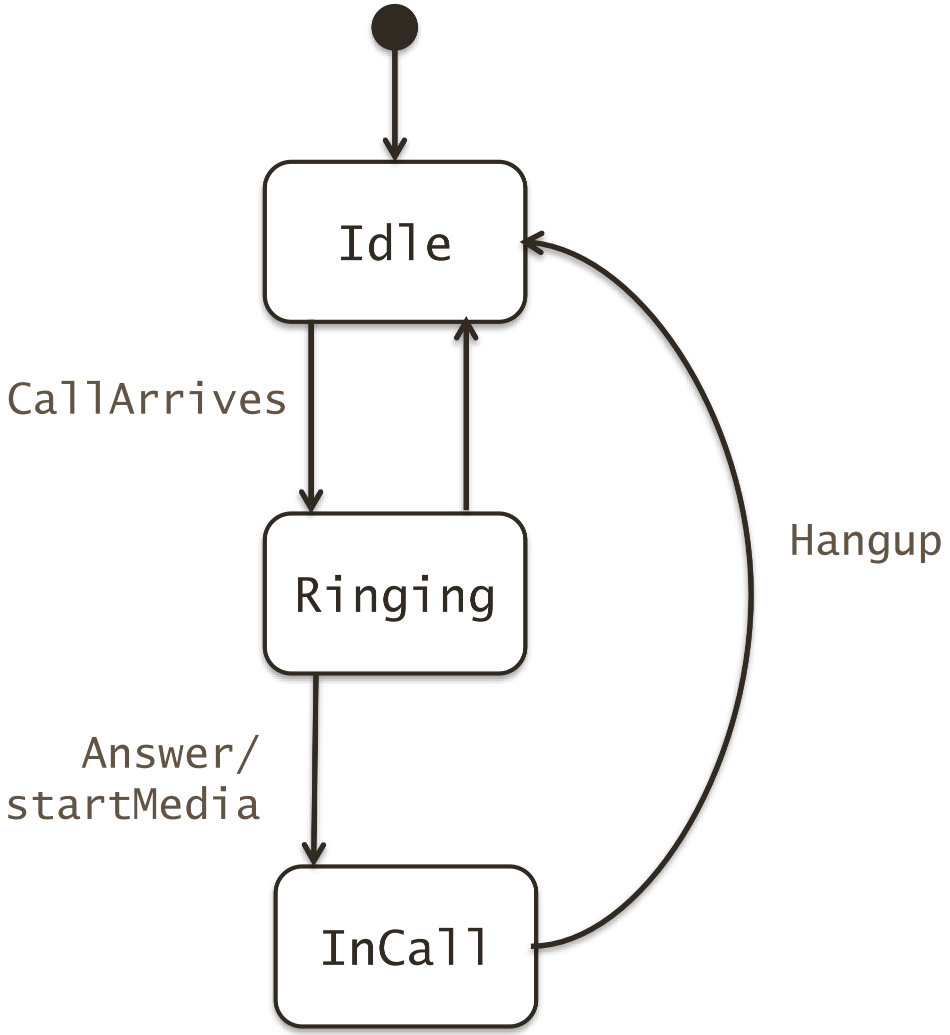
MORE ON STATES & STATE TRANSITIONS

- Examples:
  1. Credit card payment received
  2. Payment received for order
  3. Smart phone receives a call

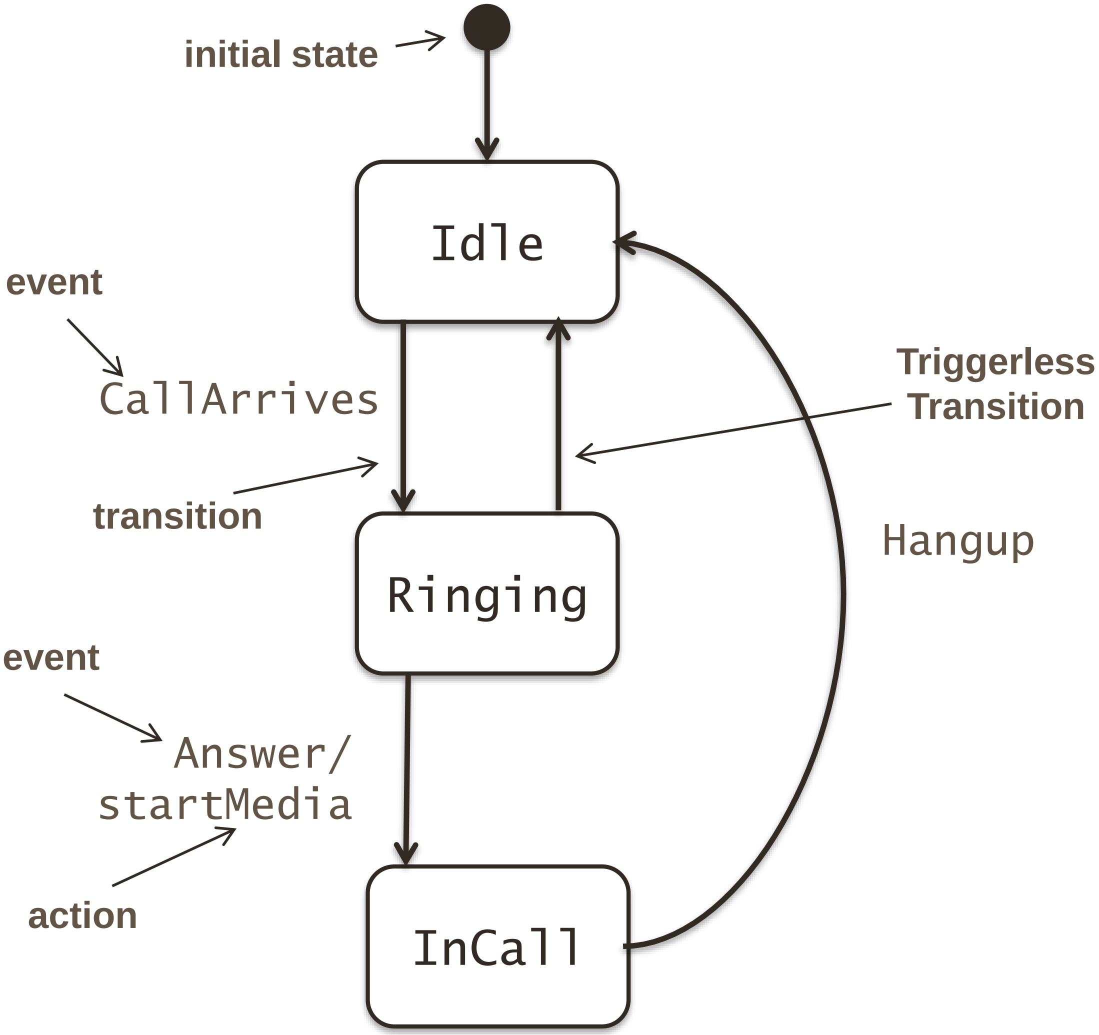
- Some events do not cause state change
  - self-transition

- A state may have an activity associated with it
  - May take longer, and may be interrupted by event
  - Fowler’s notation: do /activity inside the state

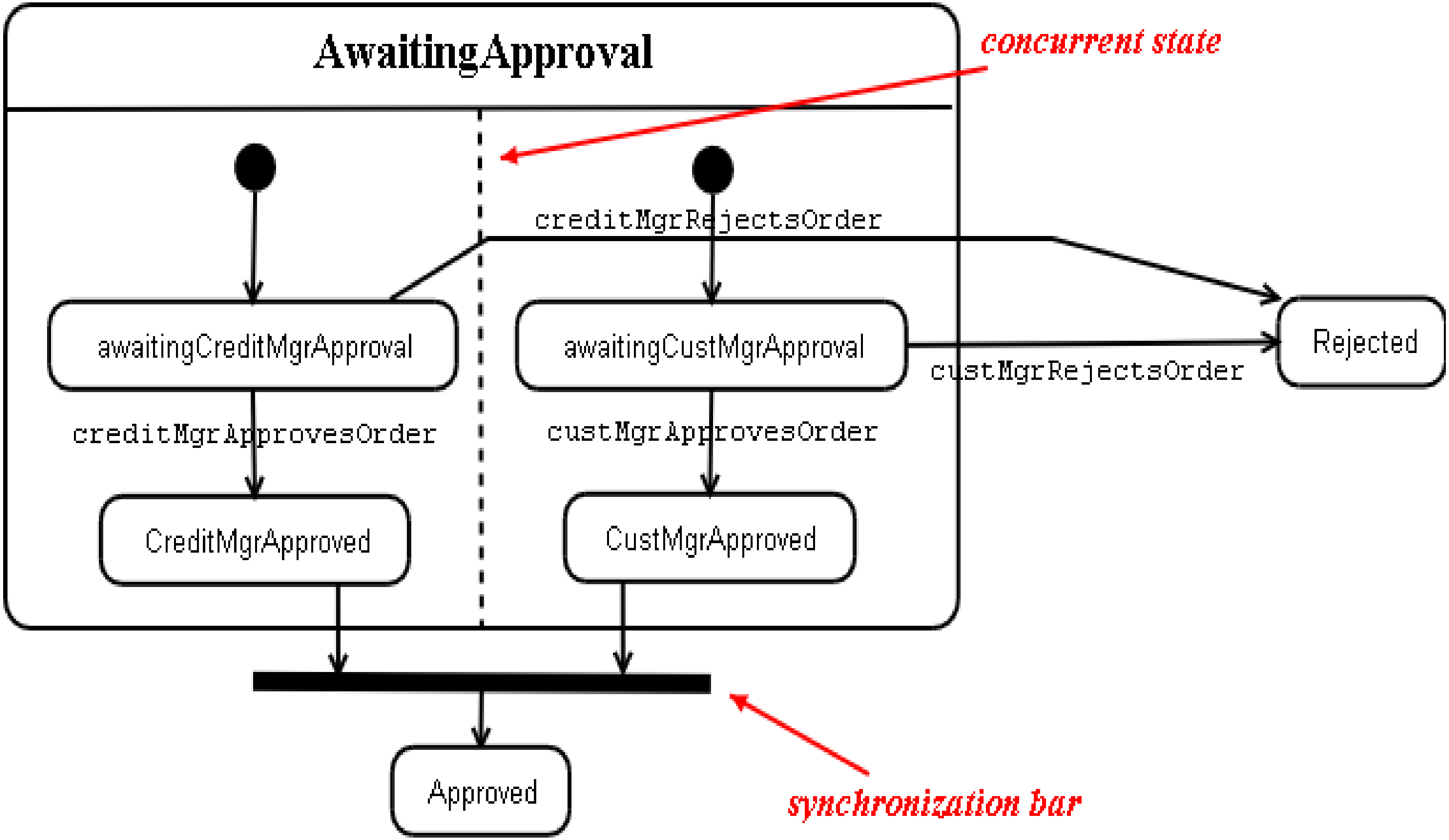
STATE DIAGRAMS: CELL PHONE EXAMPLE



STATE DIAGRAMS: CELL PHONE EXAMPLE



CONCURRENCY



STATE DIAGRAM GUIDELINES

- Keep it simple
  - if diagrams get too big:
    - *consider using composite states*
    - *or...multiple objects*

- trace through the states manually, compare against expected results

- Confirm that all states are reachable under some combination of events

- Confirm that no non-final state is a dead end

TO BE CONTINUED: MORE UML TO COME…

- Class Diagrams

- Moving from Diagrams to Code..