A Button-Led systems: from local objects to distributed systems

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1 Requirements

Every IOT system usually performs a basic set of actions:

- Acquire data from sensor devices.
- Perform some control action.
- Send commands to actuator devices.

In this very basic demo, we use a Button as a sensor and a Led as an actuator and the control action represents our business logic. Examples of the business logic implemented by our Button-Led (BLS) system are:

1. ROnOff: the Led is `turned on/off` each time the Button is pressed.
2. RBlink: when the Button is pressed, the Led `starts blinking`. When the Button is pressed again, the Led `stop blinking`. And so on.
3. ...

> Reference project: `it.unibo.bls.oo` on `https://github.com/anatali/IotUniboDemo`.

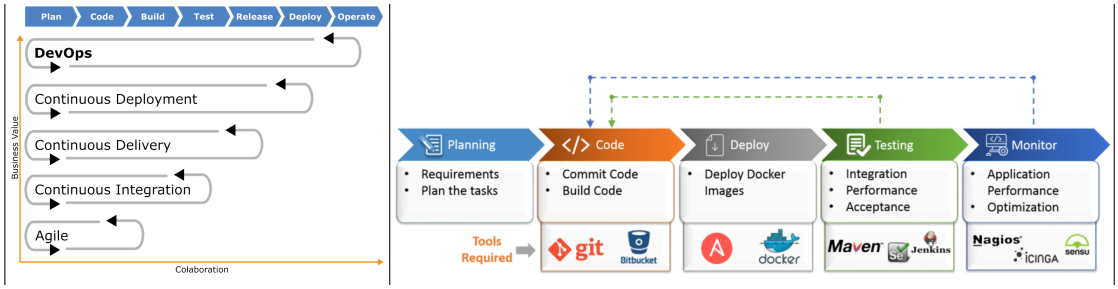
1.1 Goals

Our goals can be summarized as follows:

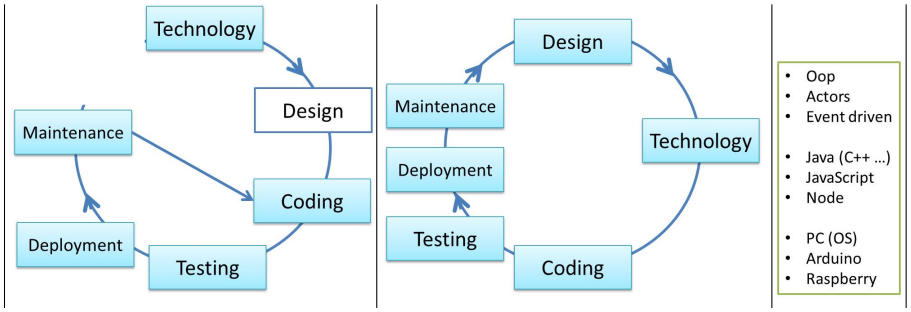
1. Define a 'technology-independent' architecture/prototype of the `BLS` in a local, tightly coupled environment.
2. Specialize the initial prototype according to different technologies. For example:
   (a) The devices are implemented as Mock objects in a virtual environment.
   (b) The devices are concrete things controlled by low-costs devices such as `Arduino/RaspberryPi`.
3. Modify the first working prototype into a loosely-coupled (distributed) system in which each device works within its own computational node: see Subsection ??.
4. Modify the distributed prototype by 'transforming' each device into a (RESTful) service.
5. ...

1.2 Software life cycle process

> Discussed in BBS-module5 : Software production.

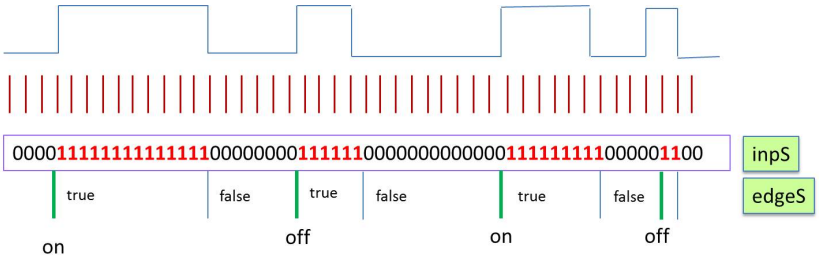


1.3 Bottom-up or Top-Down?



2 Technology-based design

The button is a source that emits a wave that can be sampled.

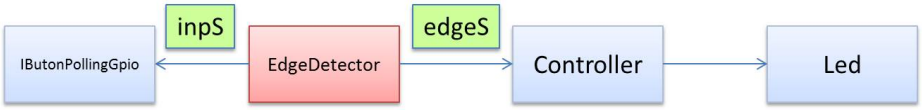


At this level, the problem requires that the following elaborations on the basic input

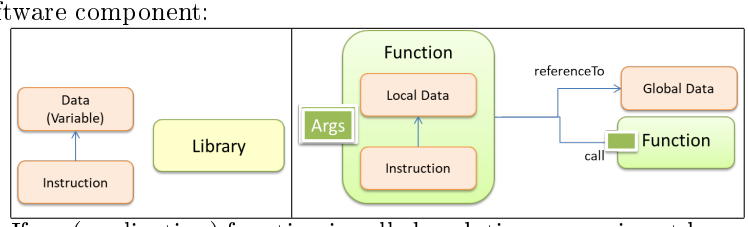
- the detection of the edges in the input sequence
- the detection of edges of type "low to high"

2.1 Function-based software

The responsibility of these functions can be given to two new different entities: an entity *EdgeDetector* and an entity *Controller* that realizes the "business logic" of the system.



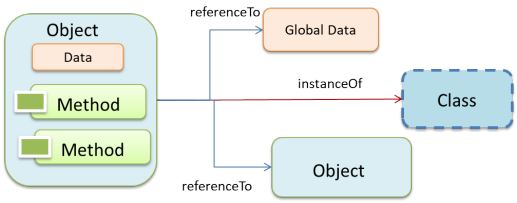
The code can be structured in imperative style, by using `functions` as a first kind of software component:



If an (application) function is called each time a new input becomes available, the system is 'reactive' or `event-driven`.

2.2 Object-based software

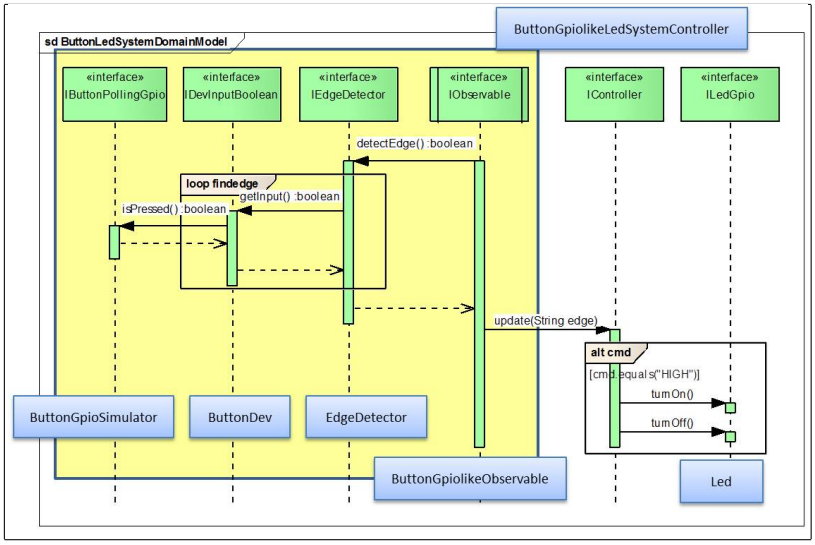
As an alternative of the function-based code of Subsection 2.1, both the *EdgeDetector* and the *Controller* can be modelled as finite state machines (`FSM`) working as *transducers*. They can be viewed as *objects* interacting via procedure-calls.



In any object-oriented model, all the computation usually takes place within a single thread. In our case the main thread could be the thread related to the component that performs the polling of the wave, i.e. the `EdgeDetector`. In this case, the *Controller* is called by the *EdgeDetector* that, must explicitly know the *Controller* in order to call it.

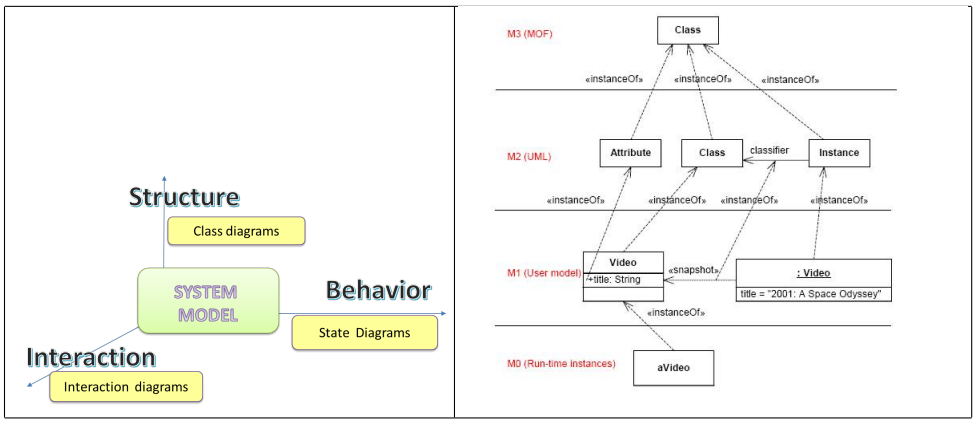
2.3 Observable and Observers

A more flexible architecture an be obtained (without changing the run-time interaction pattern) by conceiving the *Controller* as an *observer* that can be registered to the *EdgeDetector* information source.



However, staring from the idea that a Button is an 'edge detector' device is a too low-level approach for modern software applications. An effort has to be made to introduce a more appropriate `model` of the `Button` entity in terms of structure, interaction and behavior.

2.4 Models



2.5 Modelling a Button

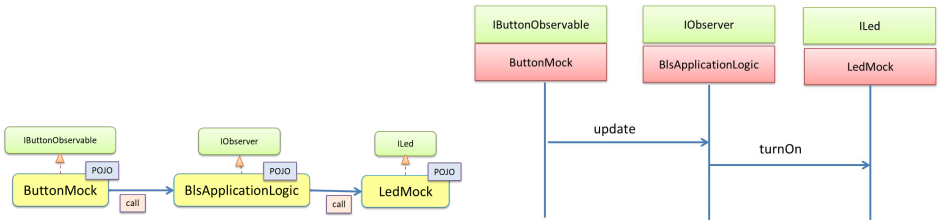
From the `structural` point of view, a button is intended by a customer as an *`atomic`* entity whose `behavior` can be modelled as a *`finite state machine`* (`FMS`) composed of two states ('`pressed`' and '`unpressed`'). The state transition is performed by some agent *external* to the system (an user, a program, a device, etc.). From the `interaction` point of view, the button can expose its internal state in different ways:

- by providing a `property` operation (e.g. `boolean isPressed()`) that returns `true` when the button is in the `pressed` state. In this way the interaction is based on "`polling`";
- by providing a `synchronizing` operation (e.g. `void waitPressed()`) that blocks a caller until the button transits in the **pressed** state. In this way the interaction is based conventional "`procedure-call`";
- by working as an `observable` according to the *Observer* design pattern. In this way the interaction is based on "`inversion of control`" and involves observers (also called "*listeners*") that must be explicitly referenced (via a "*register*" operation) by the button.
- by emitting `events` handled by an event-based support. In this way the interaction is based on "inversion of control" that involves observers (usually known as "*callbacks*") referenced by the support and not by the button itself.
- by sending `messages` handled by a message-based support. In this way the interaction is based on message passing and can follow different "patterns" (in our internal terminology we distinguish between *dispatch*, *invitation*, *request-response*, etc.)

All these "models" could be appropriate in some software application. Thus, a very useful exercise is to define in a formal way each of these models by adopting (at the moment) a test-driven approach.

3 An object-based design

Working in the conceptual space of 'classical' object oriented software development, the logic architecture of the BLS can be summarized by the following UML interaction diagram:



The computation starts from the observable device (*Button*), that calls a method of the object devoted to implement the application logic (that works as the `Observer`). An example is given in the project `it.unibo.bls.oo` that is based on the `Java` lanaguage. The working directory of the project is structured as follows:

- The package `it.unibo.bls.interfaces` includes the definition of the object interfaces.
- The package `it.unibo.bls.devices` includes the implementation of the object interfaces related to the devices (`Button` and `Led`). For each device, two different implementations are given: a `Mock` device and a 'virtual' object implemented with a `GUI`.
- The package `it.unibo.bls.applLogic` includes the definition of the object that implements the application logic.
- The package `it.unibo.bls.appl` includes the `Main` programs.
- The `test` directory includes examples of test units.

A software system working with the `Mock` devices should include a `configuration phase` to create the system components (objects) and properly connect them, according to the system architecture design:

```
1  public class MainBlsMockBase {
2  private IButton btn;
3  private ILed led;
4  //Factory method
5      public static MainBlsMockBase createTheSystem(){
6          return new MainBlsMockBase();
7      }
8      protected MainBlsMockBase( ) {
9          createComponents();
10     }
11     protected void createComponents(){
12         led = LedMock.createLed( );
13         BlsApplicationLogic applLogic = new BlsApplicationLogic(led);
14         btn = ButtonMock.createButton( applLogic );
15         led.turnOff();
16     }
```

Listing 1.1. `MainBlsMockBase.java`: configuration

The system defines also some working activity, to cause the change of the state in the `ButtonMock`:

```
1      public void doSomeJob() {
2          System.out.println("doSomeJob starts" );
3          ((ButtonMock)btn).press();
4          UtilsBls.delay(1000);
5          ((ButtonMock)btn).press();
6          System.out.println("doSomeJob ends" );
7      }
```

Listing 1.2. `MainBlsMockBase.java`: simulated action

Since every system is a **composed** (i.e. it is a non-atomic) entity, it provides also **selector-methods** to get its components:

```
    public IButton getButton(){ //introduced for testing
        return btn;
    }
    public ILed getLed(){ //introduced for testing
        return led;
    }
```

Listing 1.3. `MainBlsMockBase.java`: selectors

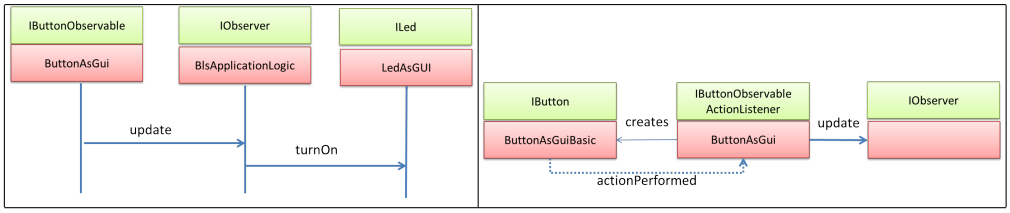
The selectors can be useful during the testing, to access the state of the single devices. Finally, there is the main method:

```
public static void main(String[] args) {
   MainBlsMockBase sys = createTheSystem();
   sys.doSomeJob();
 }
}
```

Listing 1.4. `MainBlsMockBase.java`: the main method

4 From BLS Mock devices to physical devices

The logical architecture previously introduced does not change if we replace the `Mock` devices with concrete devices: For example, in the case of virtual devices implemented with a `GUI`:



The class `ButtonAsGuiBasic` implements a `GUI`-based Button by extending the class `java.awt.Button`. The class `ButtonAsGui` implements the concept of `Button` as `Observable` entity.

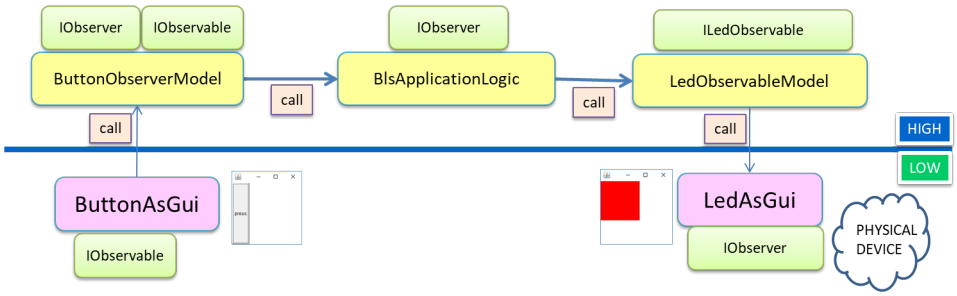
Note that `ButtonAsGui` re-uses the class `ButtonAsGuiBasic` but without exploiting inheritance. Rather, it creates an instance of `ButtonAsGuiBasic` and works as its listener. This behaviour is caused by the fact that `Java` does not support multiple inheritance for classes and `ButtonAsGui` already extends the class `java.util.Observable`.

In a more general perspective, we could build this part of our software system by exploiting the `Dependency Injection` pattern.

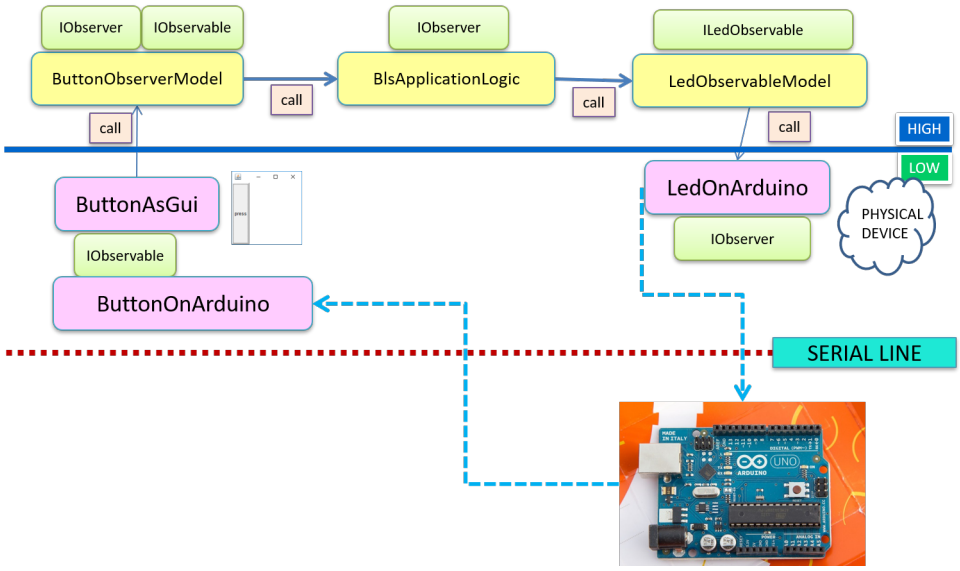
4.0.1 Dependency injection and Inversion of Control .

In software engineering, an `injection` is the passing of a dependency to a dependent object (a client) that would use it as a service. In the `dependency injection` pattern, passing the service to the client, rather than allowing a client to build or find the service, is the fundamental requirement.

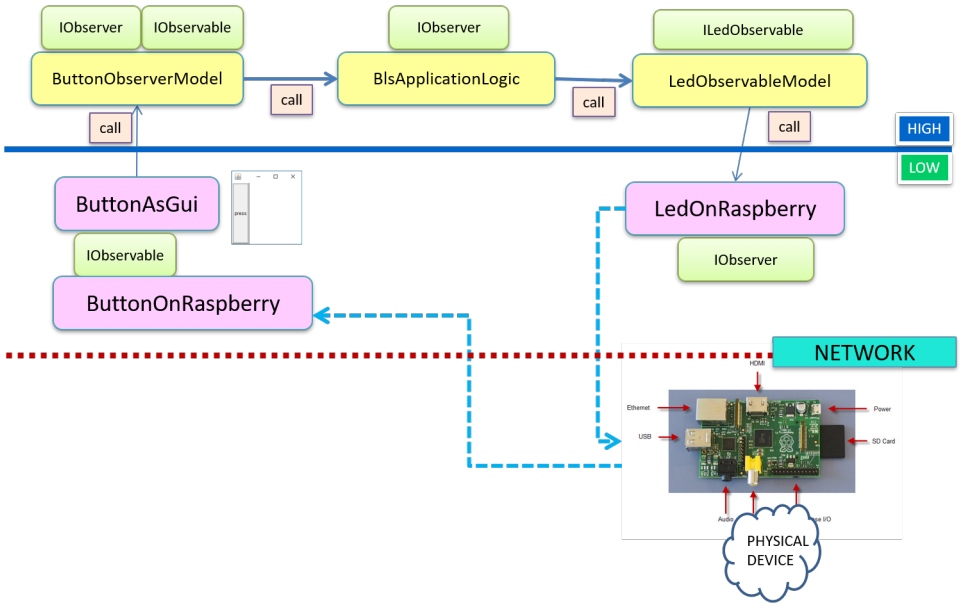
> Dependency injection is one form of the broader technique of `Inversion of Control`. The client delegates the responsibility of providing its dependencies to external code (the `injector`). The client is not allowed to call the injector code.



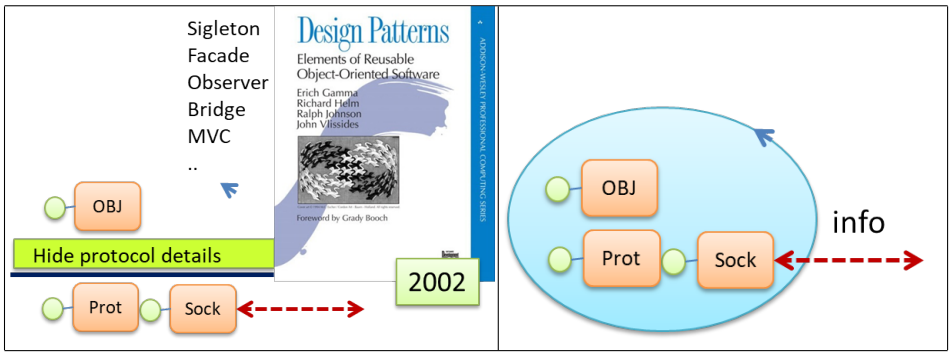
4.1 Devices on Arduino



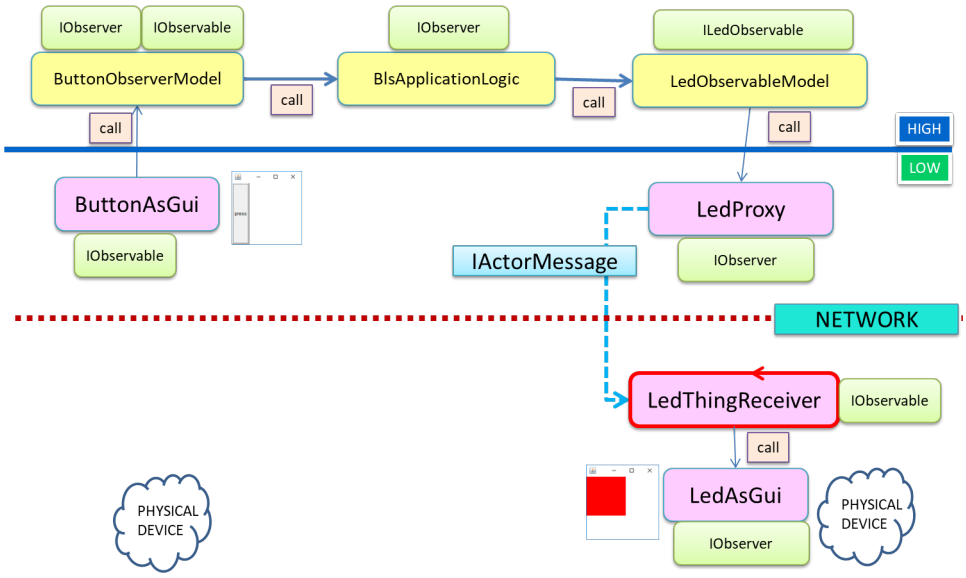
4.2 Devices on Raspberry



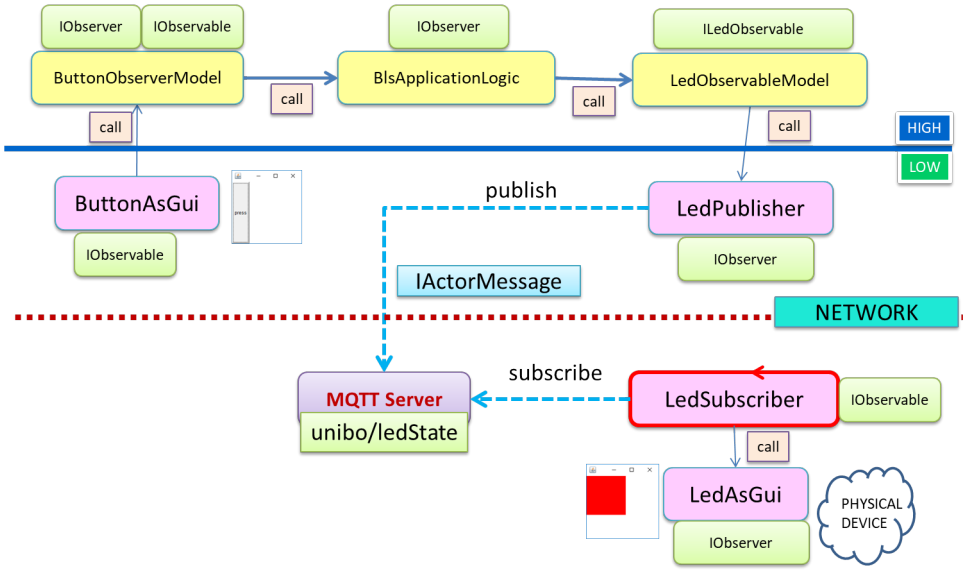
5 Evolving the BLS into a distributed system



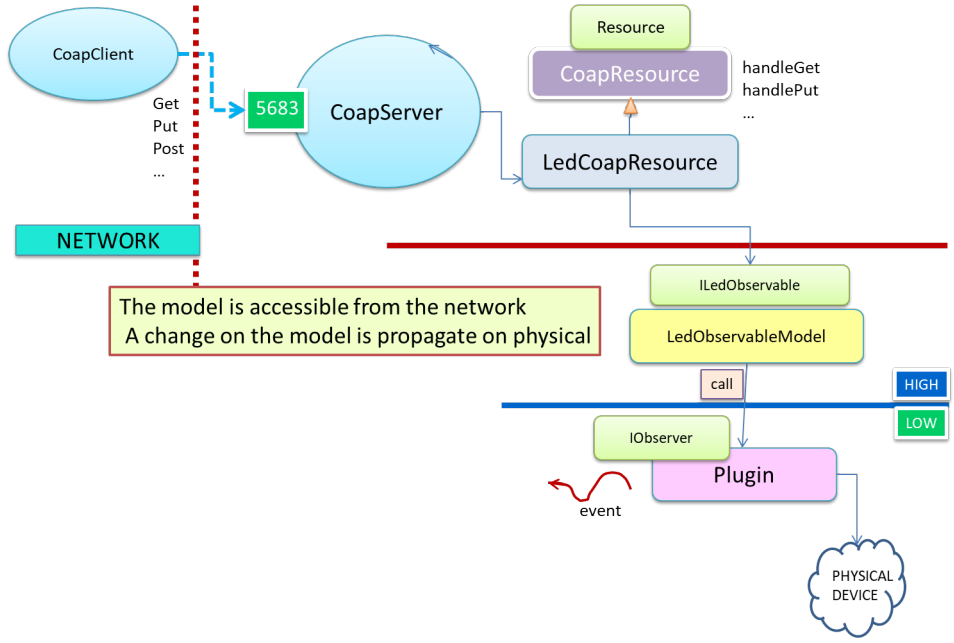
5.1 Led as a remote devices: the proxy pattern



5.2 Led as a remote device. the publish-subscribe pattern



6 CoAP



6.1 Led as a (CoAP) thing