

GitBerto:

The automated robot guide

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July 15, 2022

Abstract

In this paper we propose a small project for the *Mobile Systems* course. The project basically consists of a small robot that is piloted by a mobile device: the user sets a destination and then follows the robot that takes him to the desired location.

We underline that this work is only a very simplified description of the main operation of the system that can be extended in future developments. In this work we only develop a very simple system that shows the basic idea of this project without covering all the aspects of a real *scalable* product, but only those related with the contents of the *Mobile Systems* course with some elements derived by the course of *Ingegneria dei Sistemi Software*.

Contents

1	Introduction and fast Requirement Analysis	2
1.1	Main user story	2
1.2	Main overview of the architecture of the system	3
1.3	Code availability	4
2	Fast problem analysis	4
2.1	Connection between Android and Arduino	5
2.2	Towards Actor Modeling	6
2.2.1	Running QAK infrastructure under Android	6
2.2.2	Coroutines in Android with ViewModel	8
2.2.3	From Coroutines to QActors	10
2.2.4	Logical architecture	11

1 Introduction and fast Requirement Analysis

Since this is a small project with the aim to experiment something in *Mobile Systems*, we never provide a detailed project with exhaustive analysis. However, we will give some important details by making a fast analysis.

1.1 Main user story

This *user story* shows the main description of the operation of the system:

User Story 1.1: Main User Story

The user:

1. uses his device and **opens the GitBerto application** on his mobile that **automatically connects with the paired physical robot**;
2. inserts a destination using the classical *address searching* and the application shows the founded possibilities; then, **selects the desired target** to arrive to and the application calculates the route to get the destination;
3. **clicks on the GO** button;
4. **follows the physical GitBerto robot that started to move** guiding him towards the destination.



Figure 1: Main user story representation

The figure 1 shows a graphical representation of the steps presented in the main user

story.

1.2 Main overview of the architecture of the system

In order to simplify the work, we also make some **assumptions**:

1. angle between routes are only right (90°);
2. routes are all passable only by pedestrians;
3. all others pedestrian shows the robot and avoid collisions with him;
4. the position retrieved by the mobile device is exact without error.

These assumptions let us concentrate with the main focus of this work without caring about others aspects that are mainly related with Artificial Intelligence

As suggested by the assumption 3, as a requirement **all the computation of positions and routes must be performed by the user device**. So, as expected, **the mobile device and the robot must communicate**, exchanging commands and data.

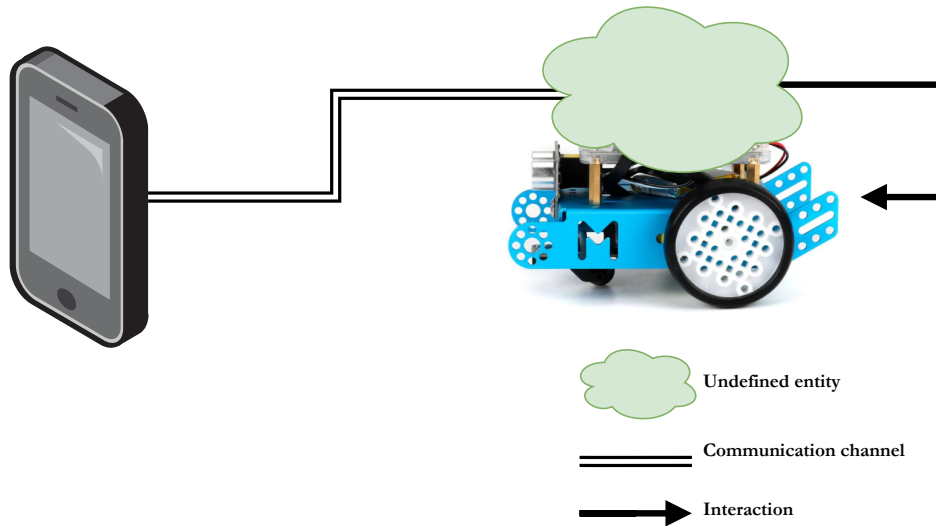


Figure 2: *Coarse* architecture of the system

The first *coarse* architecture is shown by the figure 2 that only say that:

1. there are two *undefined entities* that are *executable*: one on the device and the other on the robot;
2. this two entities has a *communication channel* that can be used for **communication**;
3. the entity on the robot can *interact* with the physical device.

About the communication, since one of the node is **mobile**, we must choose a mechanism that is supported by this type of node. So, we have restricted possibilities:

- **Bluetooth** that is fully supported from mobile devices (at least from both iOS and Android);
- **Wi-Fi Direct** that is supported too from the main mobile devices;

- **Internet protocol suite over Wi-Fi**, also supported from all devices.

Since the nodes are mobile, we exclude the set of *Internet protocol suite*. Indeed, this type of communication needs a router in order to be established. Thanks to the modern devices that now all people have, communication over Internet protocol suite implies that user might set up his phone as a Wi-Fi Hotspot, but this could introduce some possible additional costs and resource consumption (especially for battery).

About the mobile devices, is useless to say that the main options are two: **iOS** and **Android**. Since in the course of *Mobile Systems* we have studied **Android**, in this project we build the system considering only it but leaving the possibility to use the competitor in others development.

Finally, about the robot we will consider a physical robot controlled by **Arduino** or **Raspberry**. We give two main options, but the only requirement is that **the controller of the robot has to support the chosen communication mechanism**. The options we suggest are:

- **mBot**, a robot controlled by an Arduino board;
- **Nano Robot**, intended as a robot kit (like *alphabot*) with a Raspberry Pi mounted as controller.

1.3 Code availability

In the previous *fast requirement analysis* we analysed the devices and the available communication mechanisms. Now, we want to give a fast overview of the code already available. We only consider **Android** for the mobile device.

- about **communication**, Android provides a large set of components and documentation for **Bluetooth** and **Wi-Fi Direct**; we have also found some Bluetooth libraries that also work for Linux, like **PyBluez** with **Bluez** but no supports for **Wi-Fi Direct**;
- about the **robot** we have some complete supports developed by the professor Antonio Natali for the course of *Ingegneria dei Sistemi Software*, in particular we have the **BasicRobot** system.

We underline that **BasicRobot** is written by using the **QA-System** (also known as **QAK**) that is an infrastructure for **actor meta-modeling and programming**. We have full access to use this infrastructure.

2 Fast problem analysis

First, we have to resolve the main problem that comes from the requirement analysis: we said that the robot has a controller board such as **Arduino** or **Raspberry** and that it must communicate with **Android**.

Notice that even if the robot is a **mBot**, we can easily mount a **Raspberry** over **Arduino**, so we can use all the framework and the technologies that works with **Linux**. Then **we consider that the robot is controlled by a Raspberry that is well configured**.

Since we have the BasicRobot already developed and working, we decide to use it in order to build a very simple demo of the system with a mBot with a Raspberry installed over Arduino.

2.1 Connection between Android and Arduino

As shown in the fast requirement analysis, from the Android point of view we have large set of instruments to develop using Bluetooth or Wi-Fi Direct, but we can't say the same thing from the Raspberry (Linux) point of view.

We choose to use Bluetooth for communication because we have found *poor* support for Wi-Fi Direct and also because we think that Bluetooth can consume less.

Even if there are a working Python implementation of Bluetooth for Linux, we decided to make a fast porting of it because the QAK is written in Kotlin.

The entire ported library, called KBluez is fully accessible at this GitHub repository. Basically, there is a Python script ([pybluezwrapper.py](#)) launched by the Kotlin library as a system process using Java Runtime: `stdin`, `stdout` and `stderr` of the Python script are captured and handled by Kotlin that is able to send commands to PyBluez and read response by using a proper protocol.

Indeed, `pybluezwrapper.py` uses the main thread for reading commands from `stdin` that are sent by Kotlin as json strings. When the Python script receives the command to open a *Bluetooth Socket*, so `pybluezwrapper.py` launches another thread and entrust the new socket to it associating an unique identifier that Kotlin uses to refer to. **In this way, concurrency is safely guaranteed**, and it's possible to open multiple sockets without blocking the Python script.

The figure 3 shows a general overview of the architecture of our KBluez.

The figure 4 shows the class diagram of the `BluetoothSocket` interface that is the main key point of our library. Other classes will not be shown at the moment. This interface is implemented by `PyBluezSocket` class but the implementation will not be exposed in deep.

At the operational point of view, the developer can obtain a `BluetoothSocket` with `RFCOMM` by invoking:

```
1 val btSock = KBLUEZ.requestNewSocket(BluetoothServiceProtocol.RFCOMM)
```

Then, this socket can be used exactly as the internet protocol sockets in order to build a client or a server.

We have used `BluetoothSocket` implementation in order to create a bluetooth server on Raspberry that make it able to communicate with the device of the user. No library or third-party components are needed in Android.

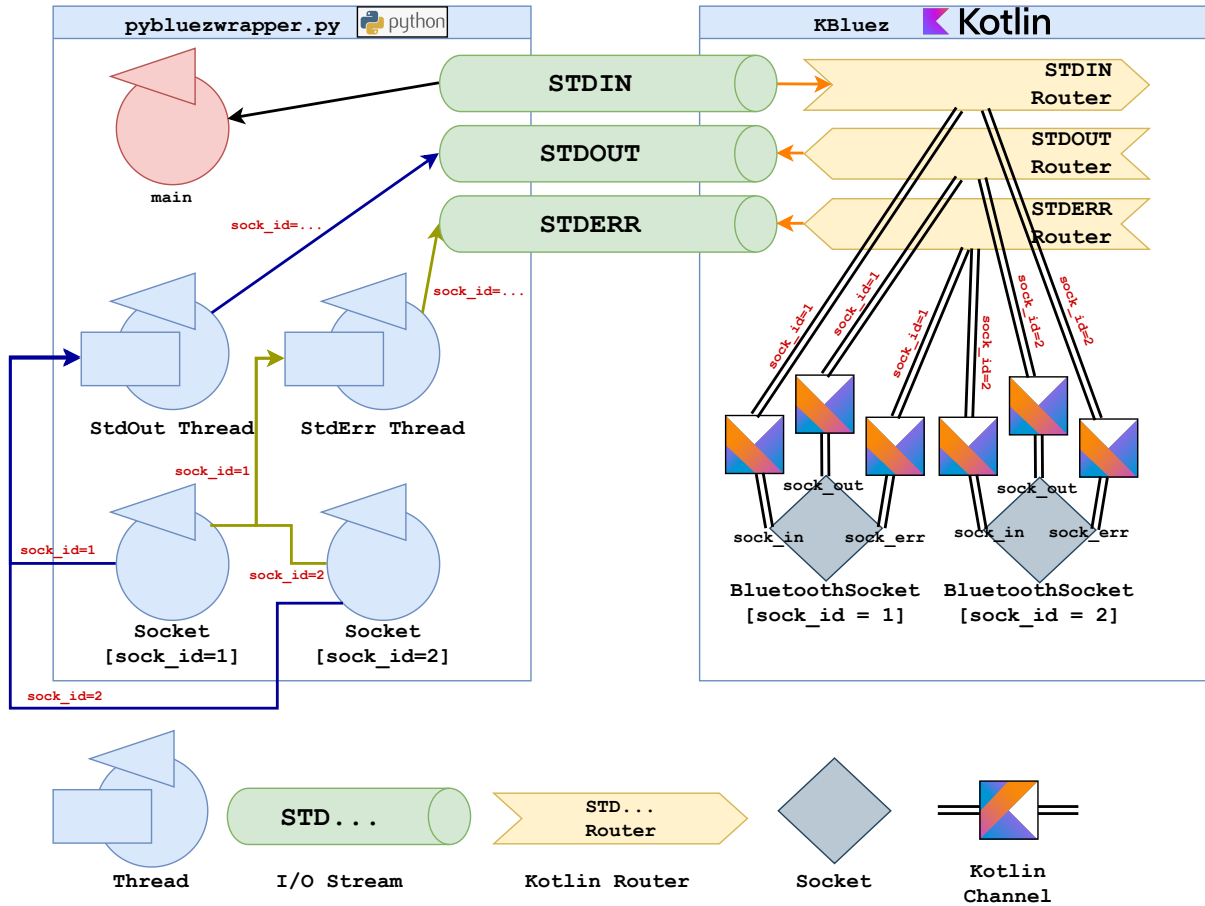


Figure 3: General architecture of the KBluez library

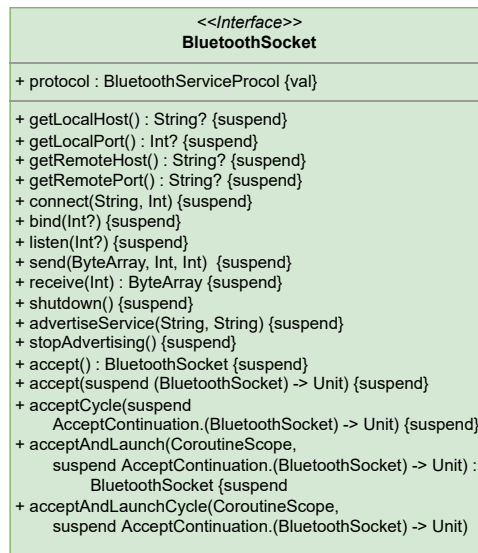


Figure 4: Class diagram of `it.unibo.kBluez.socket.BluetoothSocket`

2.2 Towards Actor Modeling

2.2.1 Running QAK infrastructure under Android

In the *Mobile System* course we study the fundamentals of Android developing. We deeply analysed all components offered to the Android developer such as Activity, Services,

Intent, Broadcast Received, AsyncTask and so on and so forth...

Now, we want to merge all of these concepts with the already mentioned **actor meta-modeling** and programming. For these purposes, as anticipated, we have the **QA-System** that is well documented at the **Github repository** of the course of *Ingegneria dei Sistemi Software*.

Just to give a fast overview, **an actor is an active entity that receives messages thanks to a channel that it owns**. So, when an actor receives a message, it performs some action depending on the contents. The QAK system make easy to define and handle actors that are mapped into Kotlin coroutines and, in addition to this, the infrastructure fully supports the concept of **actors as finite state machine** that change their internal state by receiving messages or *events*.

Using actors and QAK let us use *actor meta-modeling* as shown in this example. Once the actor meta-model is well-developed, we can execute it using QAK, but this introduces some problems related with the nature of QAK that works on normal JVM.

1. To define an actor, QAK requires its definition in a special `.pl` file that maintains all the defined actors

We have an extension of the entire QAK infrastructure made by Luca Marchegiani at QA-Extensions repository that let the developer use Annotations instead of *legacy* configuration file.

2. To define an actor, in addition to annotations or configuration file, the developer must extend `QActorBasic` or `QActorBasicFsm` classes so, since we are using Kotlin, multiple inheritance is not allowed than it is not possible to define classes that extend both `Activity` and `ActorBasicFsm`

We have created a new way to define actors that uses the newest interfaces `IQActorBasic` and `IQActorBasicFsm`.

3. QAK creates a log file for each defined actor: this is not easy in Android because of the restrictions for writing files

We have added another modification to the extensions that allows to disable file creation in `sysUtil` by adding a simple parameter to the launcher of the QA-System (see `QAKUtils.kt`).

In addition to this, notice that **Android classes are not compiled in `.class` but in `.dex`**, so the annotation scan that is present in the **QA-Extensions** does not work. To quickly resolve this problem, we choose to declare actor classes in a *hard-coded* way inside the `QAKUtils.kt`. Indeed, for extension purposes, the launcher developed in **QA-Extensions** let the developer to add some parameters, so it is easy to make additional extensions like this.

In future development it is possible to use some more accurate mechanisms such as *build time scanning* of the annotations.

2.2.2 Coroutines in Android with ViewModel

As studied in *Mobile System* course, if an Android developer has to perform a long IO operation inside an Activity, he should use other components like `AsyncTask` that, in simple terms, creates a new thread for the *long-time* operation, and *after* calls a function in which the developer can put the UI updates.

AsyncTask are now deprecated in favour of the new Kotlin concurrency utilities (see *Kotlin coroutines components in Android*).

Before we knew this, we had already decided to experiment something new such as `ViewModel` that is a component *designed to store and manage UI-related data in a lifecycle conscious way* and that can be used in combination with Kotlin coroutines.

Even without `ViewModel`, in Kotlin it is easily possible to execute pieces of concurrent code that update UI inside a coroutine. For example, suppose that you have to launch a long IO operation that loads your recipes stored into a database and have to show it on the activity:

```
1 class BluetoothConnectionActivity : AppCompatActivity() {
2
3     lateinit var tableLayout : TableLayout
4     val scope : CoroutineScope = ...
5     val recipesRepo : RecipesRepo = ...
6
7     override fun onCreate(savedInstanceState: Bundle?) {
8         tableLayout = findViewById(R.id.recipesTableLayout)
9         scope.launch {
10
11             //retrieveAll() method uses blocking network IO
12             //operations such as read from remote database
13             val recipes = recipesRepo.retrieveAll()
14
15             withContext(Dispatchers.Main) {
16                 for(recipe in recipes) {
17                     //update tableLayout with recipe...
18                 }
19             }
20         }
21     }
22 }
```

Indeed, the `launch` primitive *launches* a new coroutine that is dispatched to another thread (or to a pool of threads), but when we called `Dispatchers.Main` then the block inside is passed to the *main* thread that executes it. So, *UI* updates are performed.

As suggested by *Android* developer guide, instead of this pattern it is better to use `ViewModel` that automatically manage the lifecycle of the coroutines launched inside this. We have extended the suggested solution with this pattern:

```
1 class RecipesIO(private val recipesRepo : RecipesRepo) {
2
3     suspend fun retrieveAll() : Result<List<Recipe>> {
4         return withContext(Dispatchers.IO) {
5             return@withContext try {
```



```

6      Result.success(recipesRepo.retrieveAll())
7    } catch (e : Exception) {
8      Result.failure(e)
9    }
10  }
11 }
12
13 }
14
15 class RecipesViewModel(private val recipesIO : RecipesIO) {
16
17     private val onRetrieved = mutableListOf<
18         suspend (Result<List<Recipe>>) -> Unit>()
19
20     fun addOnRetrieved(uiUpdate : suspend (Result<List<Recipe>>) -> Unit) {
21         onRetrieved.add(uiUpdate)
22     }
23
24     fun asyncRetrieveAll() {
25         viewModelScope.launch{
26             val recipes = this@RecipesViewModel.recipesIO.retrieveAll()
27             onRetrieved.forEach { uiUpdate ->
28                 uiUpdate(recipes)
29             }
30         }
31     }
32 }
33
34
35 class BluetoothConnectionActivity : AppCompatActivity() {
36
37     lateinit var tableLayout : TableLayout
38     val recipesRepo : RecipesRepo = ...
39     val recipesViewModel = RecipesViewModel(recipesRepo)
40
41     override fun onCreate(savedInstanceState: Bundle?) {
42         tableLayout = findViewById(R.id.recipesTableLayout)
43         recipesViewModel.addOnRetrieved { result ->
44             result.onSuccess { recipes ->
45                 for(recipe in recipes) {
46                     //update tableLayout with recipe...
47                 }
48             }
49             result.onFailure { exception ->
50                 //Notify failure
51             }
52         }
53         recipesViewModel.asyncRetrieveAll()
54     }
55 }

```

Notice that `viewModelScope` is a special `CoroutineScope` owned by each `ViewModel` that automatically cancel all coroutines launched inside it if the related owner is cancelled. So, using it is totally safe!

Android let the developer use another special scope that is `LifecycleScope` (see the documentation for details).

This mechanism is very powerful but **the developer must pay attention and be careful** because if he exaggerates he should saturate the main thread if he forgets to use `Dispatcher.IO` for blocking operations.

2.2.3 From Coroutines to QActors

We have just shown that an `Activity` can launch asynchronous operations using coroutines that can also update the UI. So, what could happen if we *transform* an `Activity` into a *finite state machine actor*?

Indeed, we added some modifications to the `QA-Extensions` that let the developer define actors **using an interface** thanks to the Kotlin **delegates** that let to make something similar to the multiple inheritance.

We create the class `ActorAppCompatActivity` that automatically *configure* the actor nature of an activity. A class that extends `ActorAppCompatActivity` is an Android activity that also is a finite state machine actor. The developer must however remember to use the proper annotations on his class^a.

^aNotice that for instantiation reasons the actors that extends `ActorAppCompatActivity` must be annotated with `StartMode(TransientStartMode.MANUAL)`

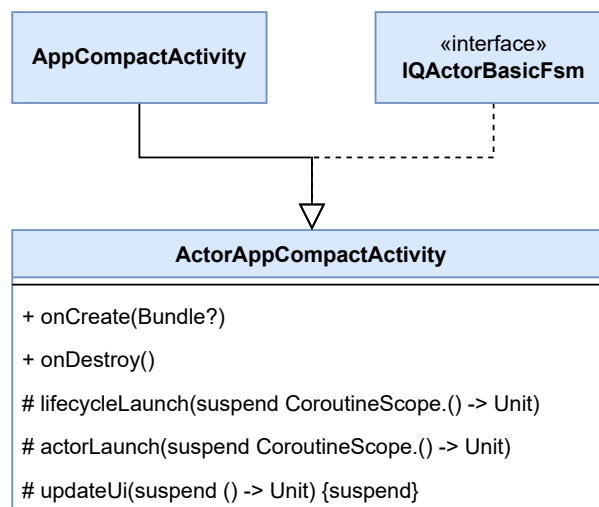


Figure 5: Class diagram of `ActorAppCompatActivity`

All the classes that extends `ActorAppCompatActivity` **must** also use `th by` keyword offered by Kotlin in order to get the implementation of the `IQActorBasicClass` following this pattern:

```

1  val APP_SCOPE = CoroutineScope(SupervisorJob() + Dispatchers.Default)
2  val DEFAULT_PARAMS = mutableParameterMap()
3  .addBlockIOParam()
4  .addAnnotatedClassesParams(
5      MainActivity :: class.java
6  )
7  .addSystemScope(APP_SCOPE)
8

```

```

9  @QActor("my_ctx")
10 @StartMode(TransientStartMode.MANUAL)
11 class MyActivity : ActorAppCompatActivity(), IQActorBasicFsm
12     by qakActorFsm(MyActivity::class.java,
13         Dispatchers.Default,
14         DEFAULT_PARAMS)
15 {
16     ...
17 }

```

If you want to add other activities, you have to add the relative class into `addAnnotatedClassesParams()` method that builds the `ParameterMap`. In addition to this, the class must be passed also in the `qakActorFsm()` method after the `by` keyword: unlucky, this code repetition is needed because we are in `Android` so we can use annotation scanning as said.

Notice also the `APP_SCOPE`: this scope is created in order to avoid the use of `GlobalScope` that is strongly discouraged.

To conclude this overview, we underline these methods:

- `lifecycleLaunch(block : suspend CoroutineScope.() -> Unit)`
launches a coroutine that executes the passed `block` using the `LifecycleCoroutineScope` associated with the lifecycle of the activity;
- `actorLaunch(block : suspend CoroutineScope.() -> Unit)`
launches a coroutine that executes the passed `block` using the `CoroutineScope` associated with the actor;
- `updateUi(block : suspend () -> Unit)`
a `suspend` function that executes the passed `block` using `Dispatchers.Main`; this method can be used from a coroutine in order to perform ui updates.

In order to prevent the overload of main thread, we decide to use the `Dispatchers.Default` as default dispatcher of all coroutines in which actor are executing, so, if an *activity actor* have to perform ui updates, he can call `updateUi` method. This is the reason why we are using the `APP_SCOPE` that is created using `Dispatchers.Default`.

2.2.4 Logical architecture

As final result of this very fast analysis, we provide the **logical architecture** of the `GitBerto` system in the figure 6.

We can also provide a small description of all the actor that will be present in the `Android` application of `GitBerto` system:

- **BluetoothActivity**
the activity that makes the user device able to establish a connection with the robot;
- **MainActivity**
the main activity that user can use to set the destination and start the trip;

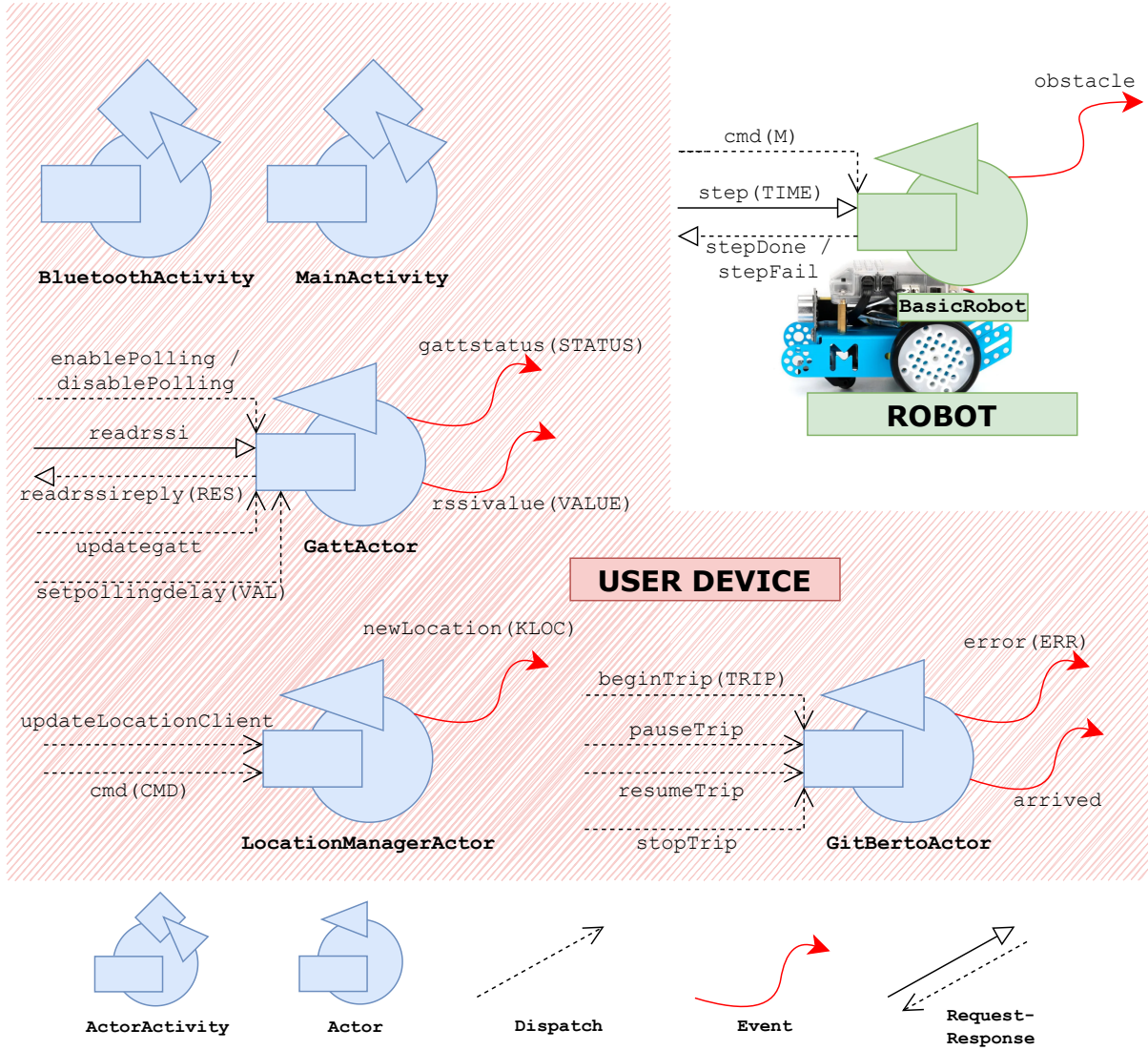


Figure 6: Logical architecture of GitBerto system

- **GattActor**
the actor that uses Bluetooth Low Energy for GATT functionality in order to continuously check the presence of the robot when the connection is established;
- **LocationManagerActor**
the actor that *manages* the location sending events when user move changing his position;
- **LocationManagerActor**
the actor that make the system able to interact with the robot using an *high level* view of it; this actor offer the main operations to manage the trip execution.