

Chapter 5

IoT Design Methodology

INTERNET OF THINGS

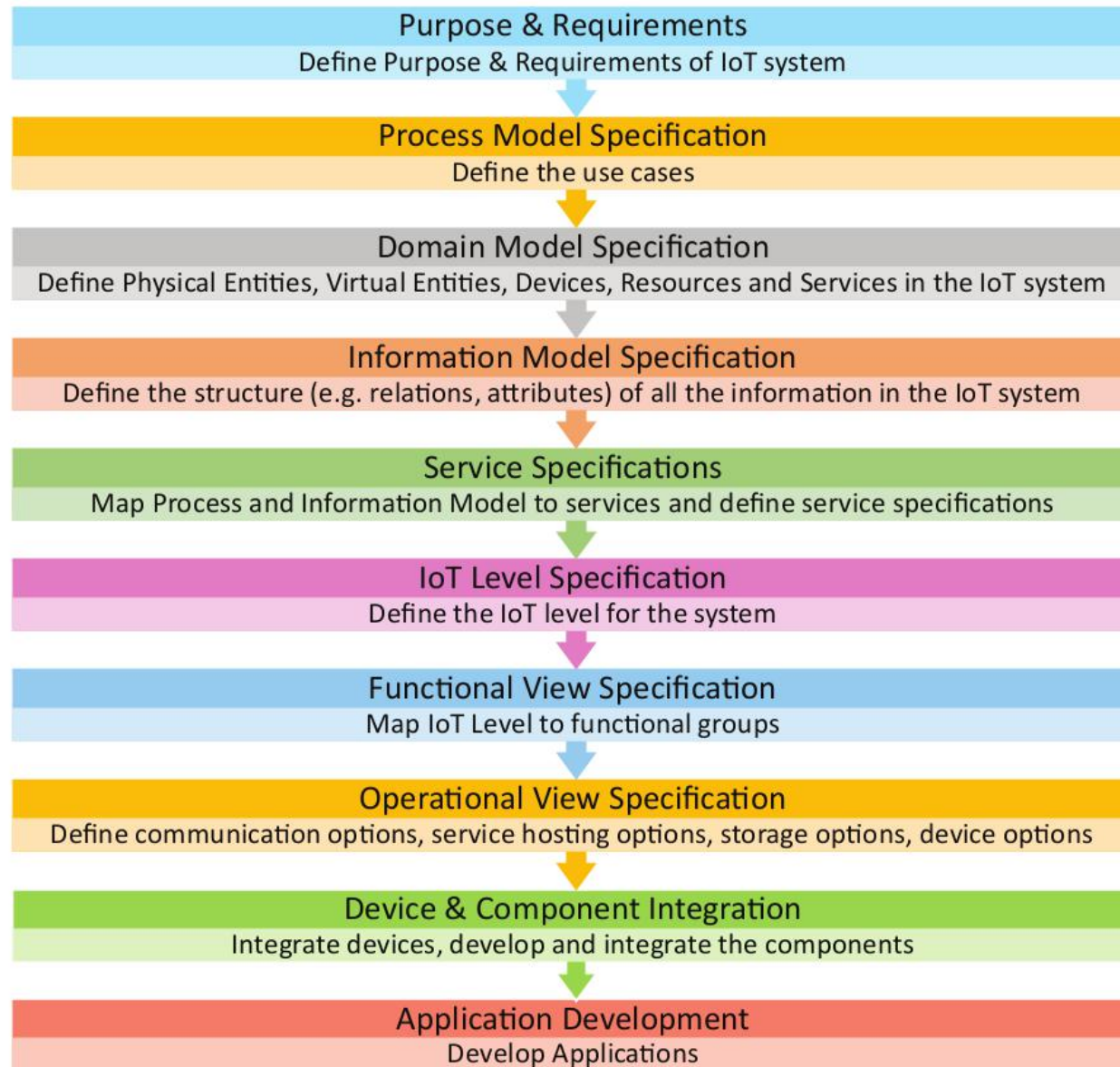
A Hands-On Approach



Outline

- IoT Design Methodology that includes:
 - Purpose & Requirements Specification
 - Process Specification
 - Domain Model Specification
 - Information Model Specification
 - Service Specifications
 - IoT Level Specification
 - Functional View Specification
 - Operational View Specification
 - Device & Component Integration
 - Application Development

IoT Design Methodology - Steps



Step 1: Purpose & Requirements Specification

- The first step in IoT system design methodology is to define the purpose and requirements of the system. In this step, the **system purpose, behavior** and requirements (such as **data collection** requirements, **data analysis** requirements, **system management** requirements, **data privacy** and **security** requirements, **user interface** requirements, ...) are captured.

Step 2: Process Specification

- The second step in the IoT design methodology is to define the process specification. In this step, the **use cases** of the IoT system are formally described **based on and derived from the purpose and requirement specifications.**

Step 3: Domain Model Specification

- The third step in the IoT design methodology is to define the Domain Model. The domain model describes the **main concepts**, **entities** and **objects in the domain of IoT system** to be designed. Domain model defines the **attributes** of the objects and **relationships between objects**. Domain model provides an **abstract representation** of the concepts, objects and entities in the IoT domain, **independent of any specific technology or platform**. With the domain model, the IoT system designers can get an **understanding** of the IoT domain for which the system is to be designed.

Step 4: Information Model Specification

- The fourth step in the IoT design methodology is to define the Information Model. Information Model defines the structure of all the information in the IoT system, for example, attributes of Virtual Entities, relations, etc. Information model does not describe the specifics of how the information is represented or stored. To define the information model, we first list the Virtual Entities defined in the Domain Model. Information model adds more details to the Virtual Entities by defining their attributes and relations.

Step 5: Service Specifications

- The fifth step in the IoT design methodology is to define the service specifications. Service specifications define the **services** in the IoT system, service **types**, service **inputs/output**, service **endpoints**, service **schedules**, service **preconditions** and service **effects**.

Step 6: IoT Level Specification

- The sixth step in the IoT design methodology is to define the IoT level for the system. In Chapter-1, we defined five IoT deployment levels.

Step 7: Functional View Specification

- The seventh step in the IoT design methodology is to define the Functional View. The Functional View (FV) defines the functions of the IoT systems grouped into various Functional Groups (FGs). Each Functional Group either provides functionalities for interacting with instances of concepts defined in the Domain Model or provides information related to these concepts.

Step 8: Operational View Specification

- The eighth step in the IoT design methodology is to define the Operational View Specifications. In this step, various options pertaining to the IoT system deployment and operation are defined, such as, service hosting options, storage options, device options, application hosting options, etc

Step 9: Device & Component Integration

- The ninth step in the IoT design methodology is the integration of the devices and components.

Step 10: Application Development

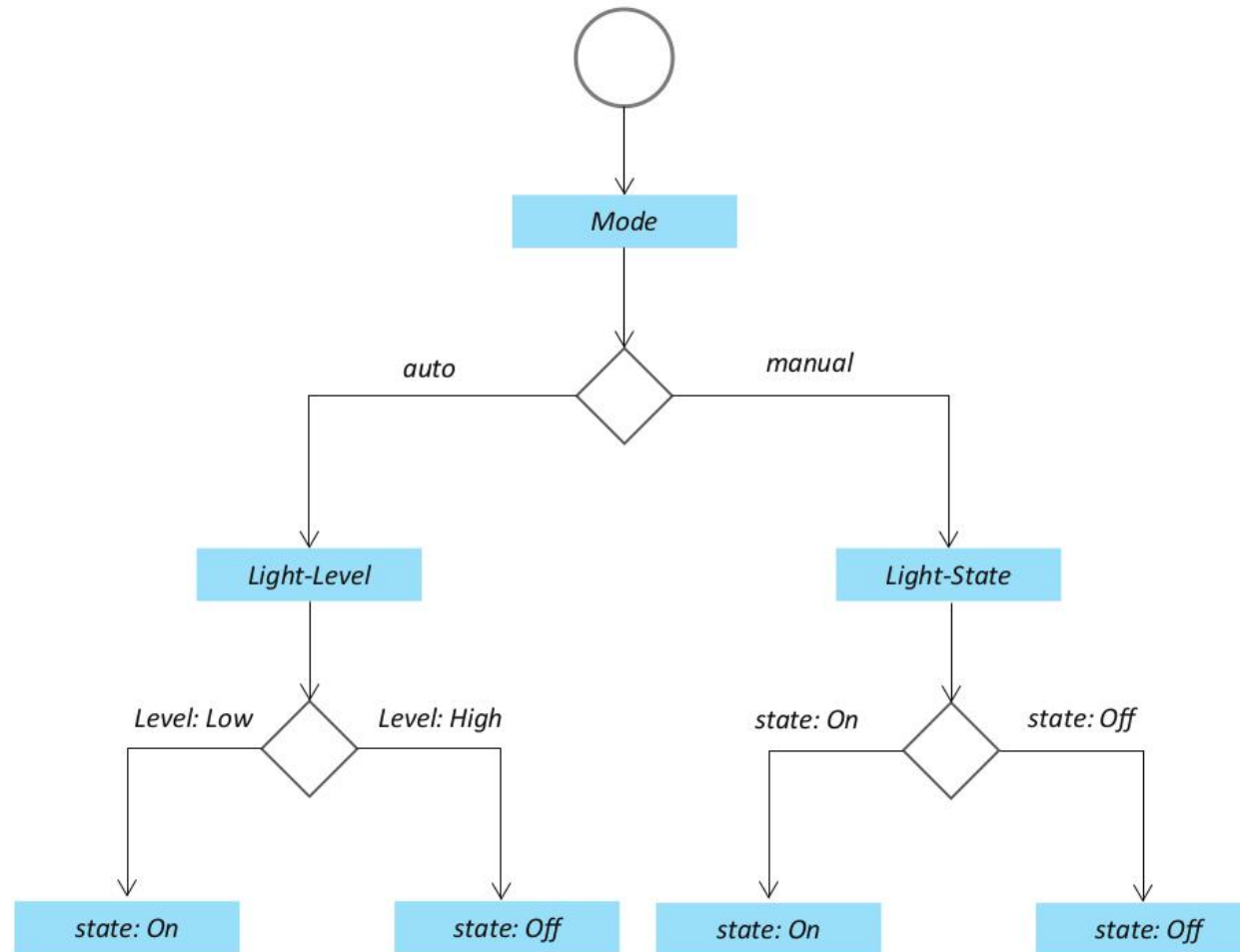
- The final step in the IoT design methodology is to develop the IoT application.

Home Automation Case Study

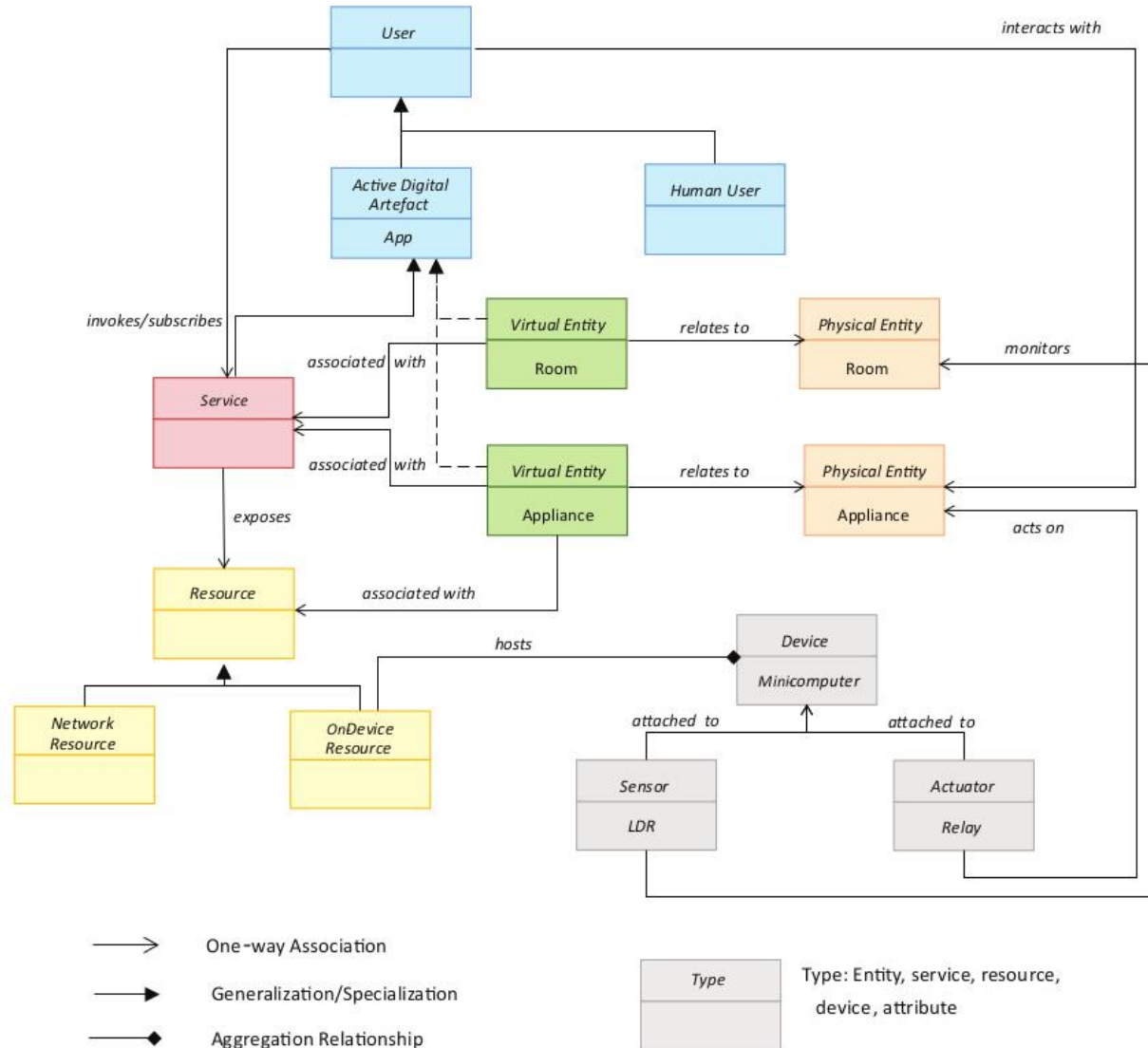
Step:1 - Purpose & Requirements

- Applying this to our example of a smart home automation system, the purpose and requirements for the system may be described as follows:
 - **Purpose** : A home automation system that allows **controlling of the lights in a home remotely using a web application**.
 - **Behavior** : The home automation system should have **auto and manual modes**. In auto mode, the system measures the light level in the room and switches on the light when it gets dark. In manual mode, the system provides the option of manually and remotely switching on/off the light.
 - **System Management Requirement** : The system should provide **remote monitoring and control functions**.
 - **Data Analysis Requirement** : The system should perform **local analysis** of the data.
 - **Application Deployment Requirement** : The application should be **deployed locally** on the device, but should be **accessible remotely**.
 - **Security Requirement** : The system should have **basic user authentication** capability.

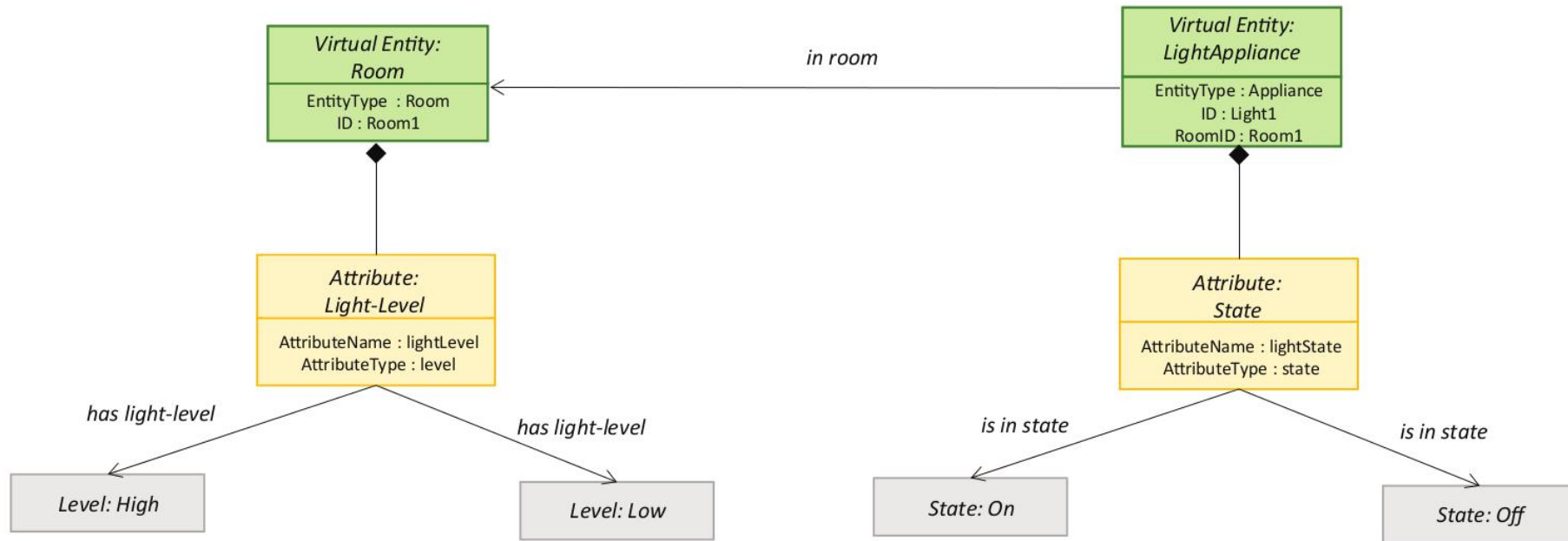
Step:2 - Process Specification



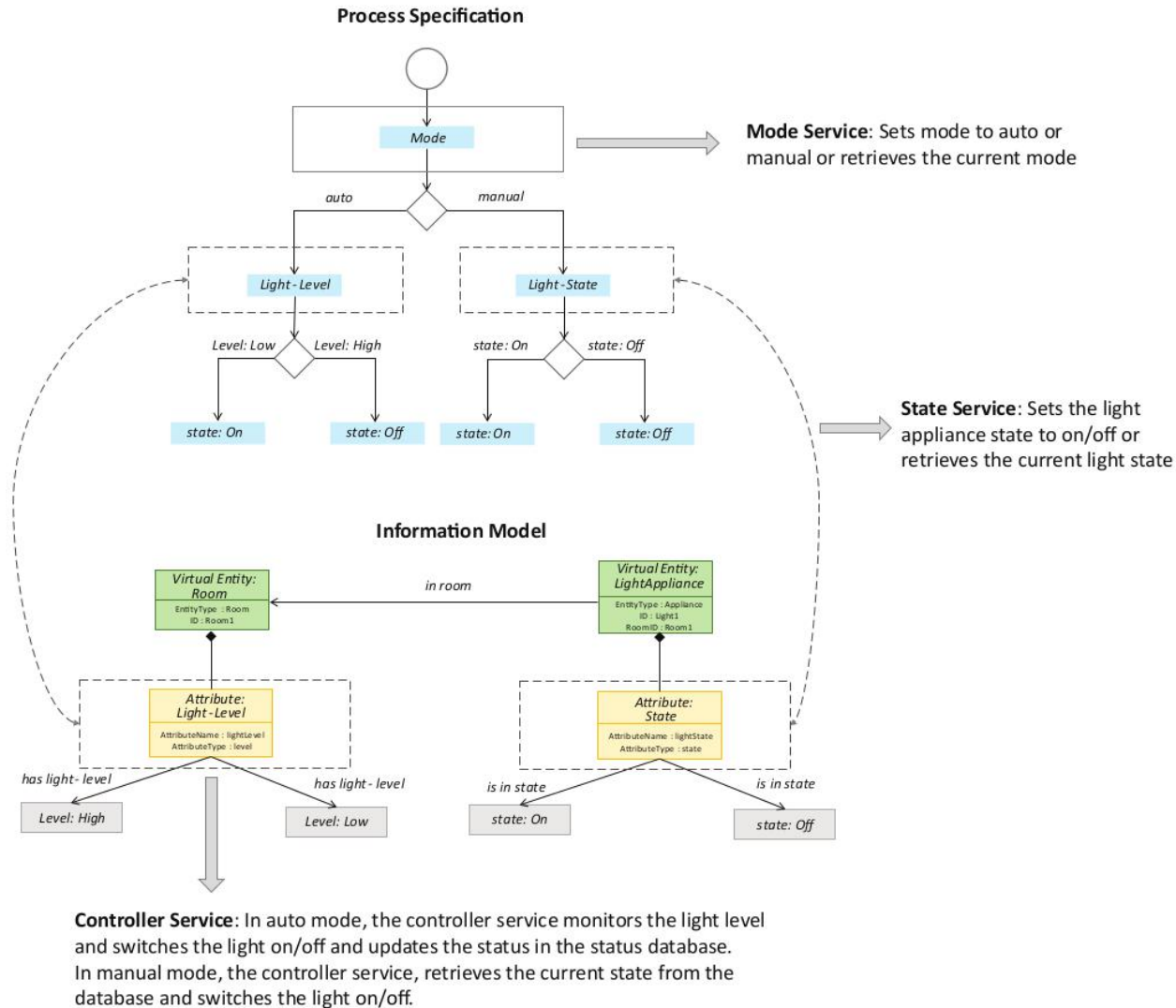
Step 3: Domain Model Specification



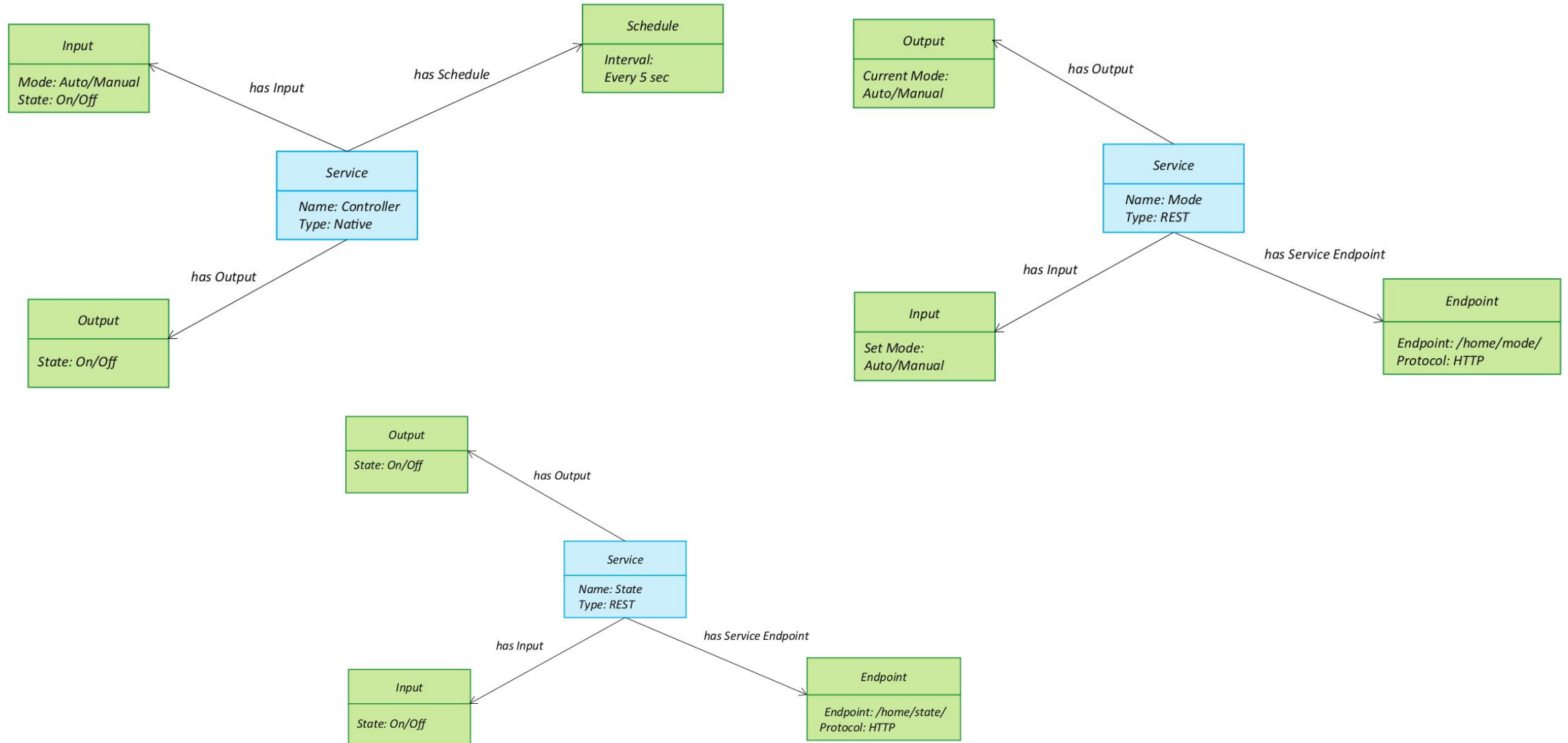
Step 4: Information Model Specification



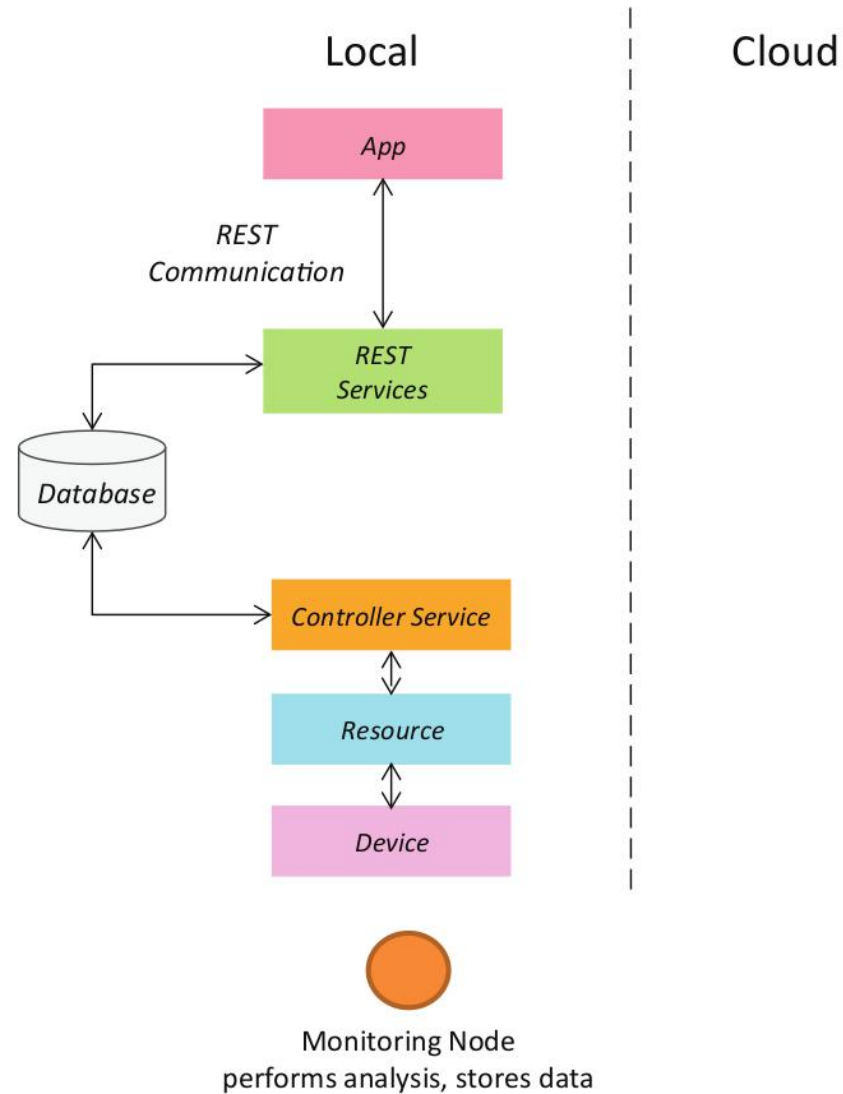
Step 5: Service Specifications



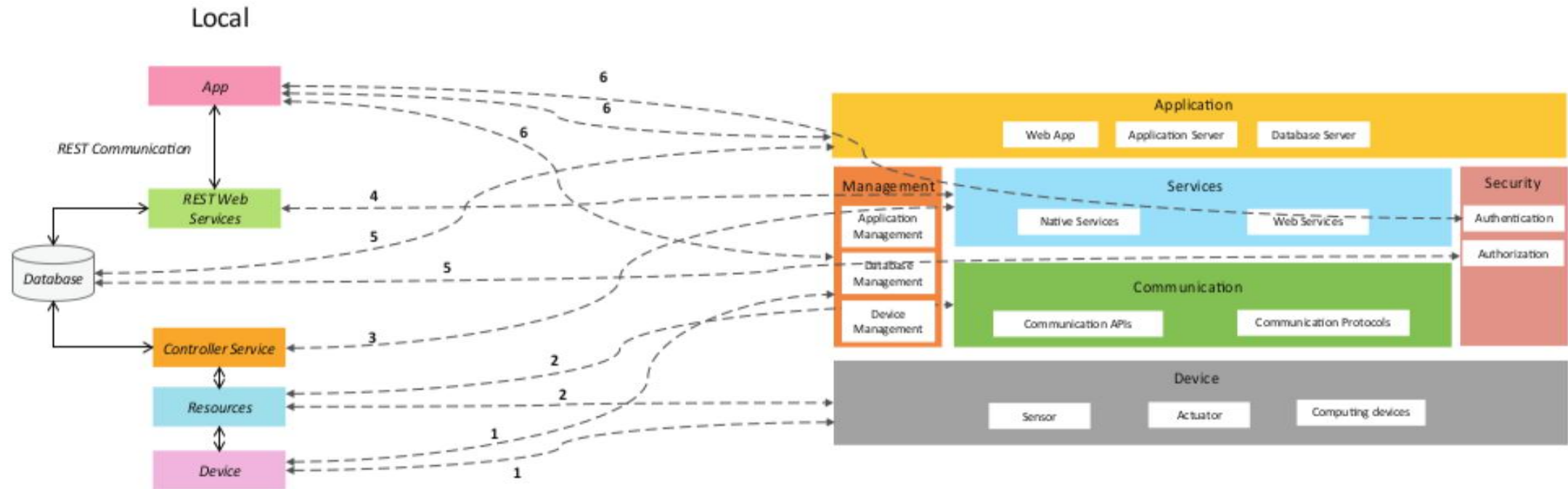
Step 5: Service Specifications



Step 6: IoT Level Specification



Step 7: Functional View Specification



1. IoT device maps to the Device FG (sensors, actuators devices, computing devices) and the Management FG (device management)

4. Web Services map to Services FG (web services)

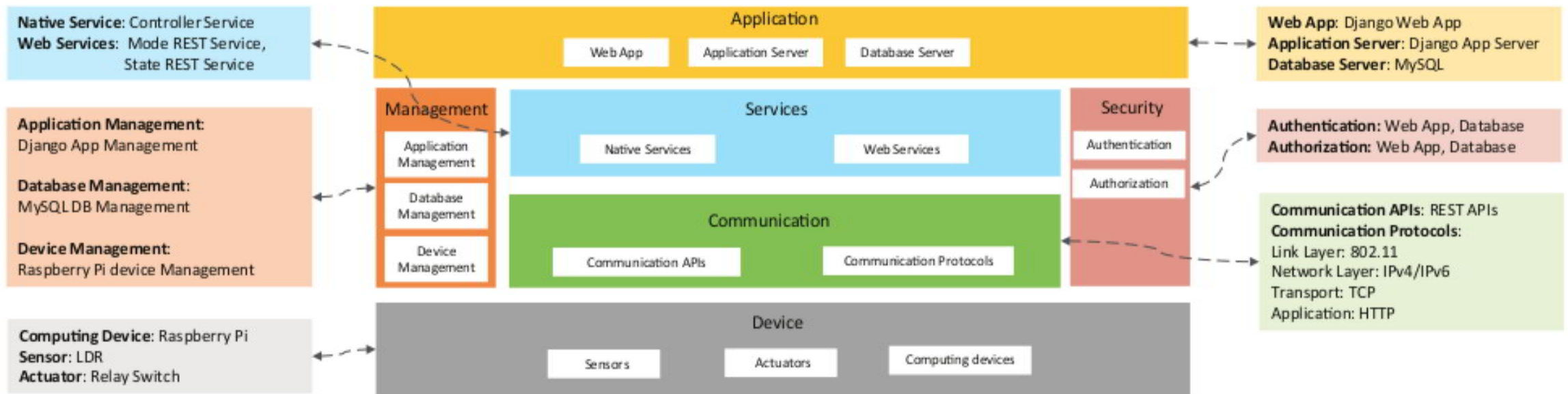
2. Resources map to the Device FG (on-device resource) and Communication FG (communication APIs and protocols)

5. Database maps to the Management FG (database management) and Security FG (database security)

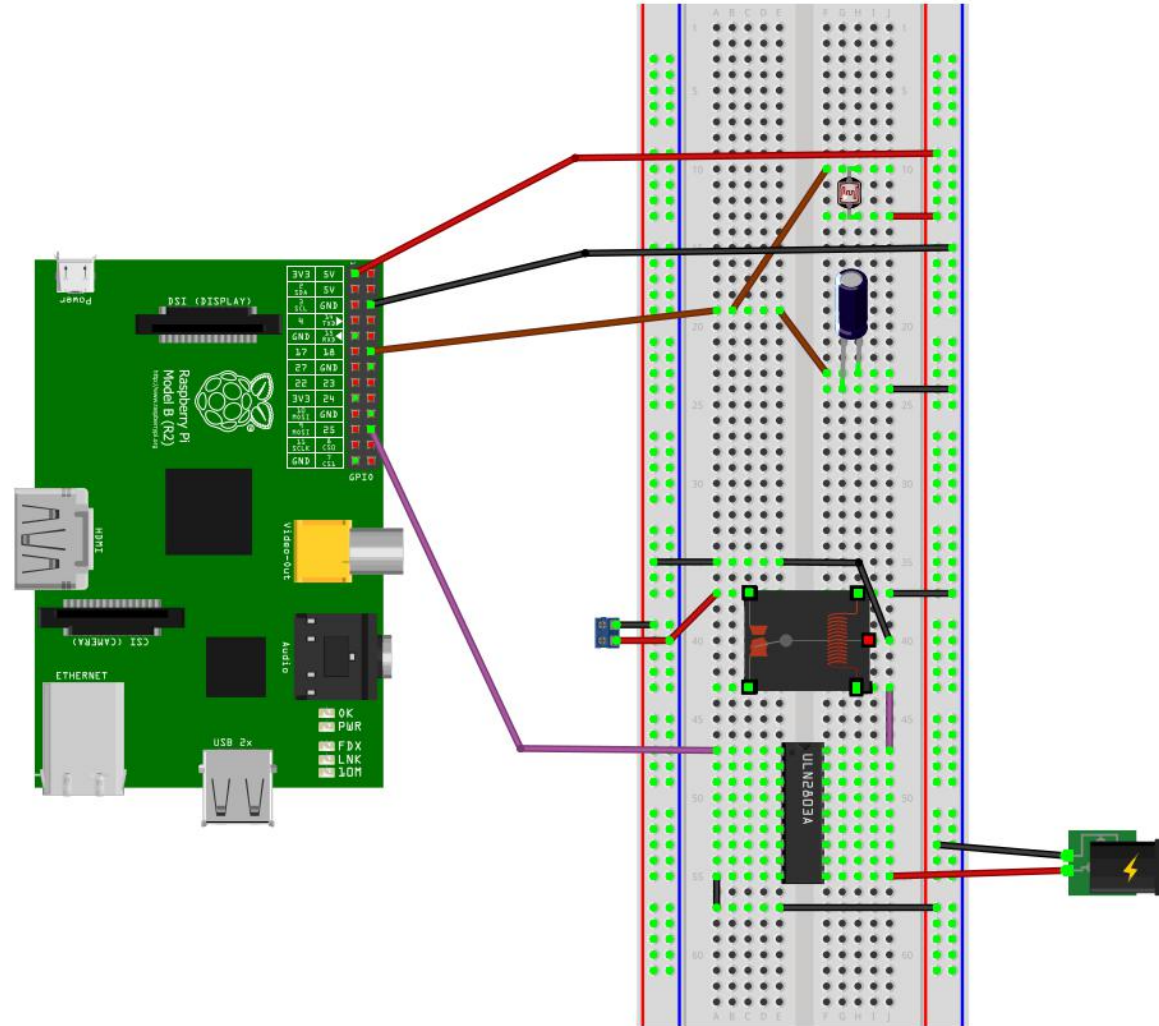
3. Controller service maps to the Services FG (native service). Web Services map to Services FG (web services)

6. Application maps to the Application FG (web application, application and database servers), Management FG (app management) and Security FG (app security)

Step 8: Operational View Specification

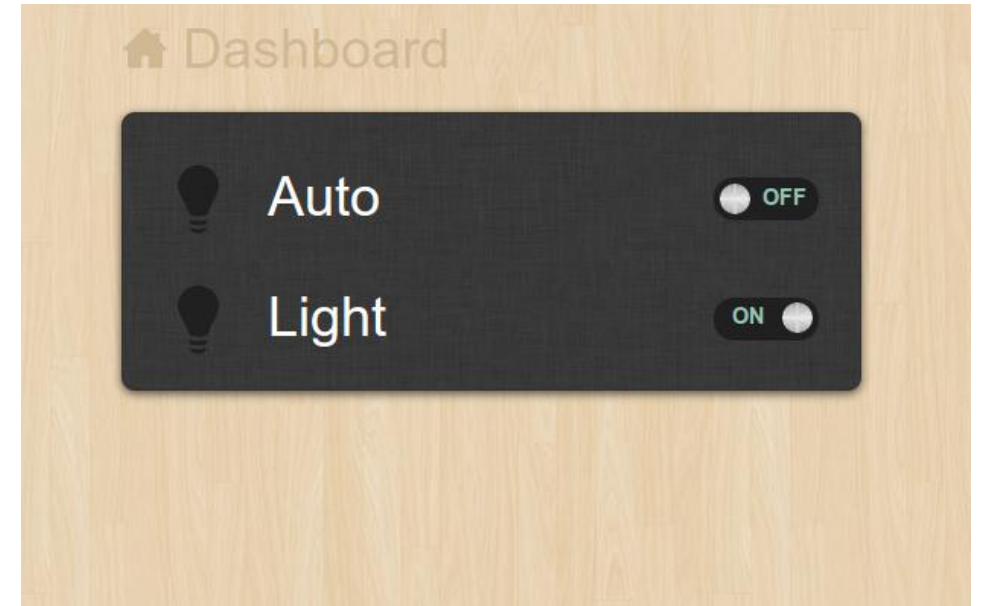


Step 9: Device & Component Integration



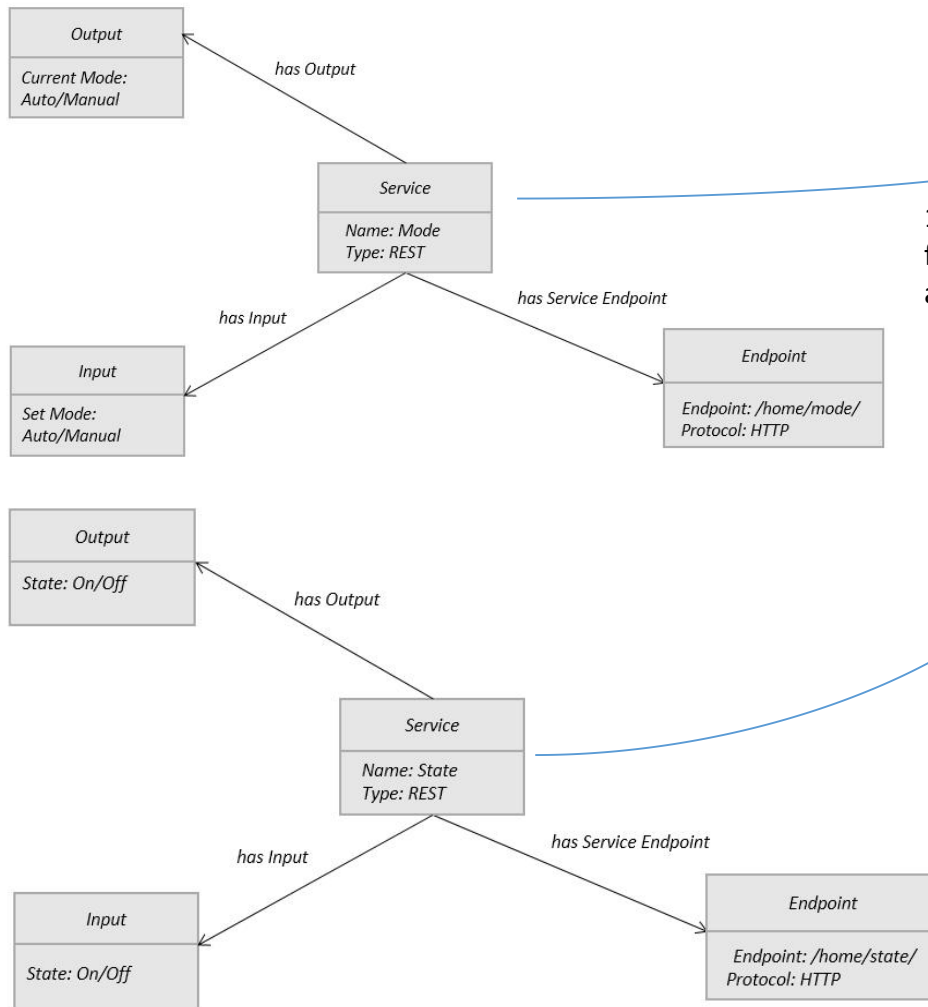
Step 10: Application Development

- Auto
 - Controls the light appliance automatically based on the lighting conditions in the room
- Light
 - When Auto mode is off, it is used for manually controlling the light appliance.
 - When Auto mode is on, it reflects the current state of the light appliance.



Implementation: RESTful Web Services

REST services implemented with Django REST Framework



1. Map services to models. Model fields store the states (on/off, auto/manual)

```
# Models – models.py
from django.db import models

class Mode(models.Model):
    name = models.CharField(max_length=50)

class State(models.Model):
    name = models.CharField(max_length=50)
```

2. Write Model serializers. Serializers allow complex data (such as model instances) to be converted to native Python datatypes that can then be easily rendered into JSON, XML or other content types.

```
# Serializers – serializers.py
from myapp.models import Mode, State
from rest_framework import serializers

class ModeSerializer(serializers.HyperlinkedModelSerializer):
    class Meta:
        model = Mode
        fields = ('url', 'name')

class StateSerializer(serializers.HyperlinkedModelSerializer):
    class Meta:
        model = State
        fields = ('url', 'name')
```

Implementation: RESTful Web Services


Models – models.py

```
from django.db import models

class Mode(models.Model):
    name = models.CharField(max_length=50)

class State(models.Model):
    name = models.CharField(max_length=50)
```

3. Write ViewSets for the Models which combine the logic for a set of related views in a single class.



Views – views.py

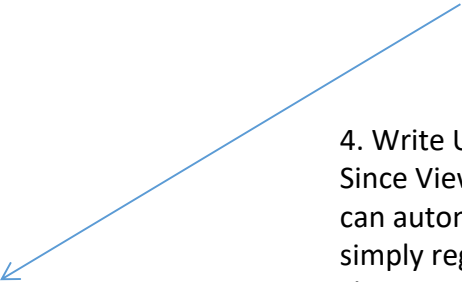
```
from myapp.models import Mode, State
from rest_framework import viewsets
from myapp.serializers import ModeSerializer, StateSerializer

class ModeViewSet(viewsets.ModelViewSet):
    queryset = Mode.objects.all()
    serializer_class = ModeSerializer

class StateViewSet(viewsets.ModelViewSet):
    queryset = State.objects.all()
    serializer_class = StateSerializer
```

URL Patterns – urls.py

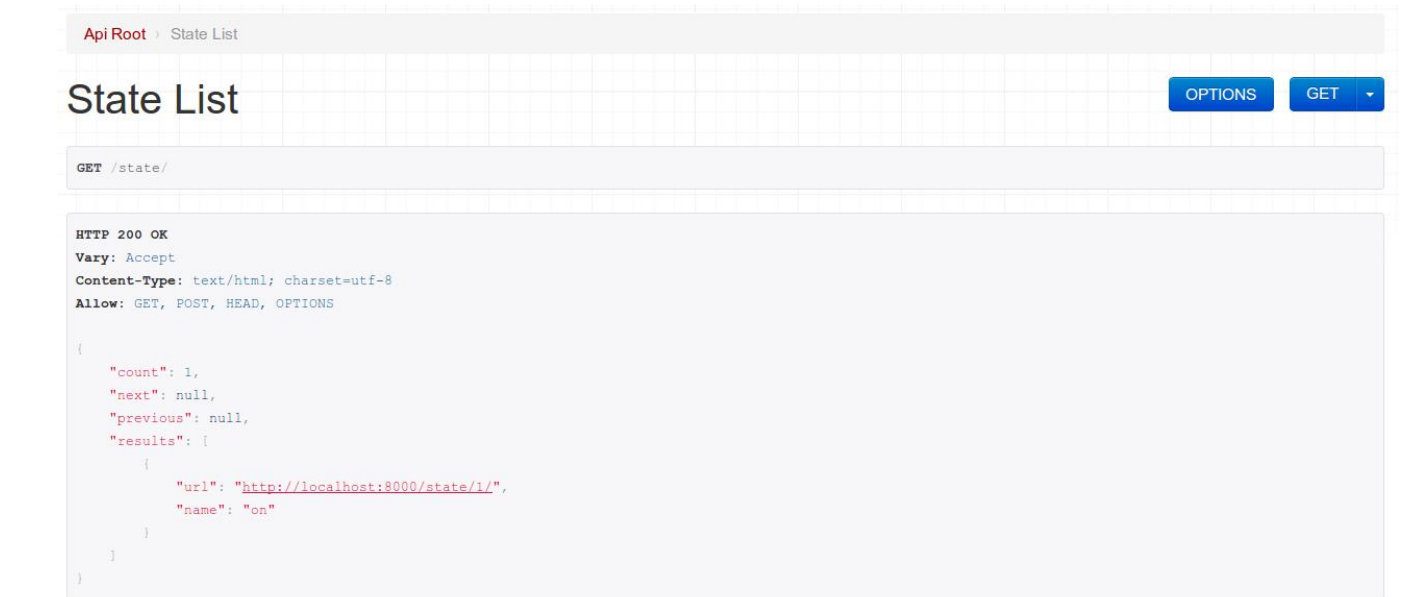
```
from django.conf.urls import patterns, include, url
from django.contrib import admin
from rest_framework import routers
from myapp import views
admin.autodiscover()
router = routers.DefaultRouter()
router.register(r'mode', views.ModeViewSet)
router.register(r'state', views.StateViewSet)
urlpatterns = patterns("",
    url(r'^$', include(router.urls)),
    url(r'^api-auth/', include('rest_framework.urls', namespace='rest_framework')),
    url(r'^admin/', include(admin.site.urls)),
    url(r'^home/', 'myapp.views.home'),
)
```



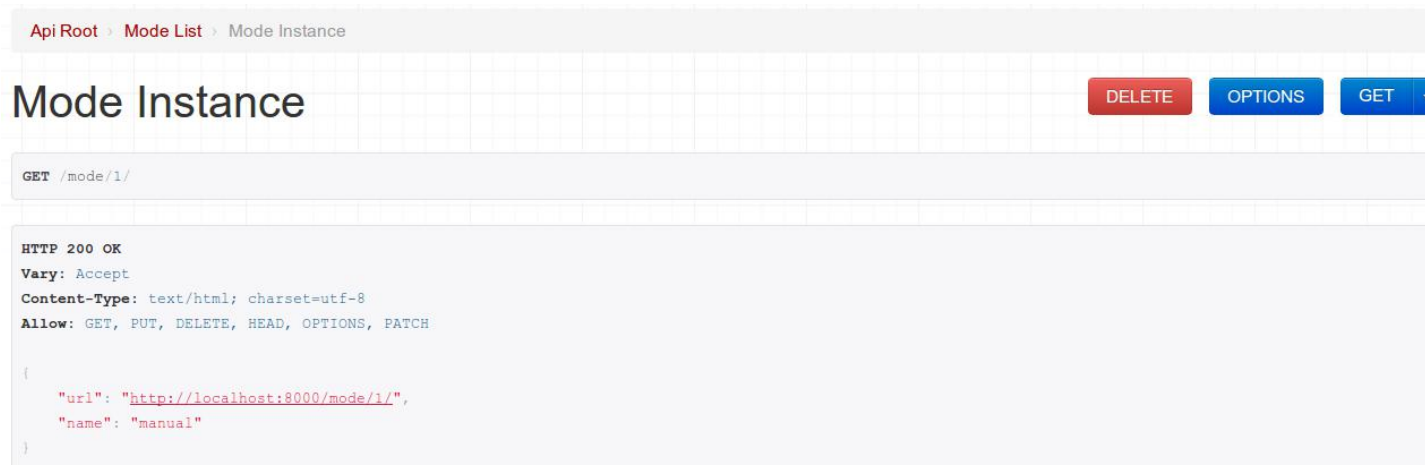
4. Write URL patterns for the services. Since ViewSets are used instead of views, we can automatically generate the URL conf by simply registering the viewsets with a router class. Routers automatically determining how the URLs for an application should be mapped to the logic that deals with handling incoming requests.

Implementation: RESTful Web Services

Screenshot of browsable
State REST API

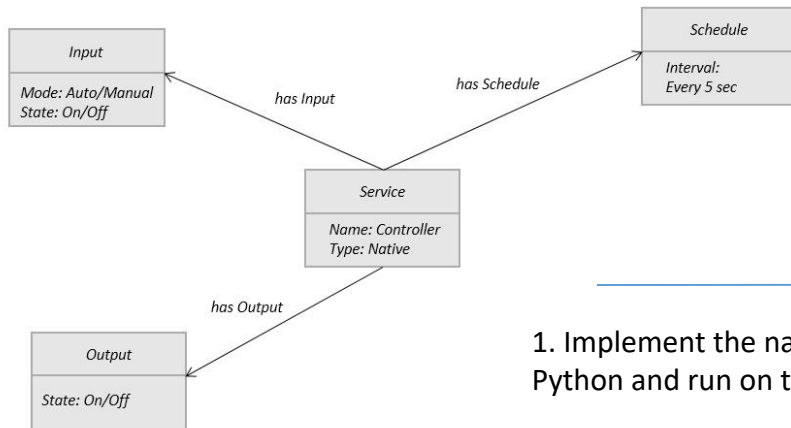


Screenshot of browsable
Mode REST API



Implementation: Controller Native Service

Native service deployed locally



1. Implement the native service in Python and run on the device

#Controller service

```
import RPi.GPIO as GPIO
import time
import sqlite3 as lite
import sys
```

```
con = lite.connect('database.sqlite')
cur = con.cursor()
```

```
GPIO.setmode(GPIO.BCM)
threshold = 1000
LDR_PIN = 18
LIGHT_PIN = 25
```

```
def readLdr(PIN):
    reading=0
    GPIO.setup(PIN, GPIO.OUT)
    GPIO.output(PIN, GPIO.LOW)
    time.sleep(0.1)
    GPIO.setup(PIN, GPIO.IN)
    while (GPIO.input(PIN)==GPIO.LOW):
        reading=reading+1
    return reading
```

```
def switchOnLight(PIN):
    GPIO.setup(PIN, GPIO.OUT)
    GPIO.output(PIN, GPIO.HIGH)
```

```
def switchOffLight(PIN):
    GPIO.setup(PIN, GPIO.OUT)
    GPIO.output(PIN, GPIO.LOW)
```

```
def runAutoMode():
    ldr_reading = readLdr(LDR_PIN)
    if ldr_reading < threshold:
        switchOnLight(LIGHT_PIN)
        setCurrentState('on')
    else:
        switchOffLight(LIGHT_PIN)
        setCurrentState('off')

def runManualMode():
    state = getCurrentState()
    if state=='on':
        switchOnLight(LIGHT_PIN)
        setCurrentState('on')
    elif state=='off':
        switchOffLight(LIGHT_PIN)
        setCurrentState('off')

def getCurrentMode():
    cur.execute('SELECT * FROM myapp_mode')
    data = cur.fetchone()      #(1, u'auto')
    return data[1]

def getCurrentState():
    cur.execute('SELECT * FROM myapp_state')
    data = cur.fetchone()      #(1, u'on')
    return data[1]

def setCurrentState(val):
    query='UPDATE myapp_state set name="'+val+'"'
    cur.execute(query)

while True:
    currentMode=getCurrentMode()
    if currentMode=='auto':
        runAutoMode()
    elif currentMode=='manual':
        runManualMode()
    time.sleep(5)
```

Implementation: Application

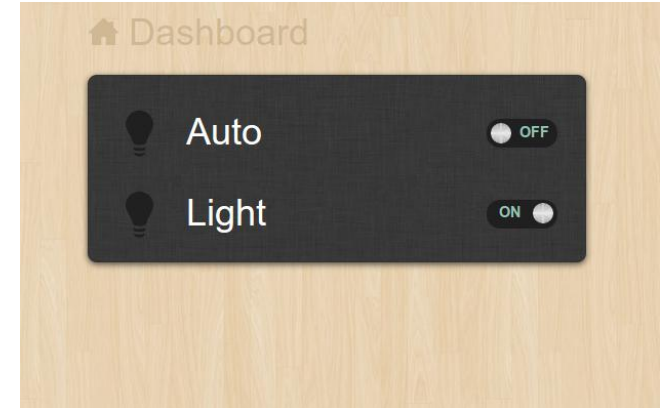
1. Implement Django Application View

```
# Views – views.py
def home(request):
    out=""
    if 'on' in request.POST:
        values = {"name": "on"}
        r=requests.put('http://127.0.0.1:8000/state/1/', data=values, auth=('username', 'password'))
        result=r.text
        output = json.loads(result)
        out=output['name']
    if 'off' in request.POST:
        values = {"name": "off"}
        r=requests.put('http://127.0.0.1:8000/state/1/', data=values, auth=('username', 'password'))
        result=r.text
        output = json.loads(result)
        out=output['name']
    if 'auto' in request.POST:
        values = {"name": "auto"}
        r=requests.put('http://127.0.0.1:8000/mode/1/', data=values, auth=('username', 'password'))
        result=r.text
        output = json.loads(result)
        out=output['name']
    if 'manual' in request.POST:
        values = {"name": "manual"}
        r=requests.put('http://127.0.0.1:8000/mode/1/', data=values, auth=('username', 'password'))
        result=r.text
        output = json.loads(result)
        out=output['name']

    r=requests.get('http://127.0.0.1:8000/mode/1/', auth=('username', 'password'))
    result=r.text
    output = json.loads(result)
    currentmode=output['name']
    r=requests.get('http://127.0.0.1:8000/state/1/', auth=('username', 'password'))
    result=r.text
    output = json.loads(result)
    currentstate=output['name']
    return render_to_response('lights.html',{r':out, 'currentmode':currentmode, 'currentstate':currentstate},
    context_instance=RequestContext(request))
```

Implementation: Application

2. Implement Django Application Template

[illegible]

Finally - Integrate the System

- Setup the device
- Deploy and run the REST and Native services
- Deploy and run the Application
- Setup the database

