CSCI E-97 Software Design 9/15/2020

Smart City Design Document

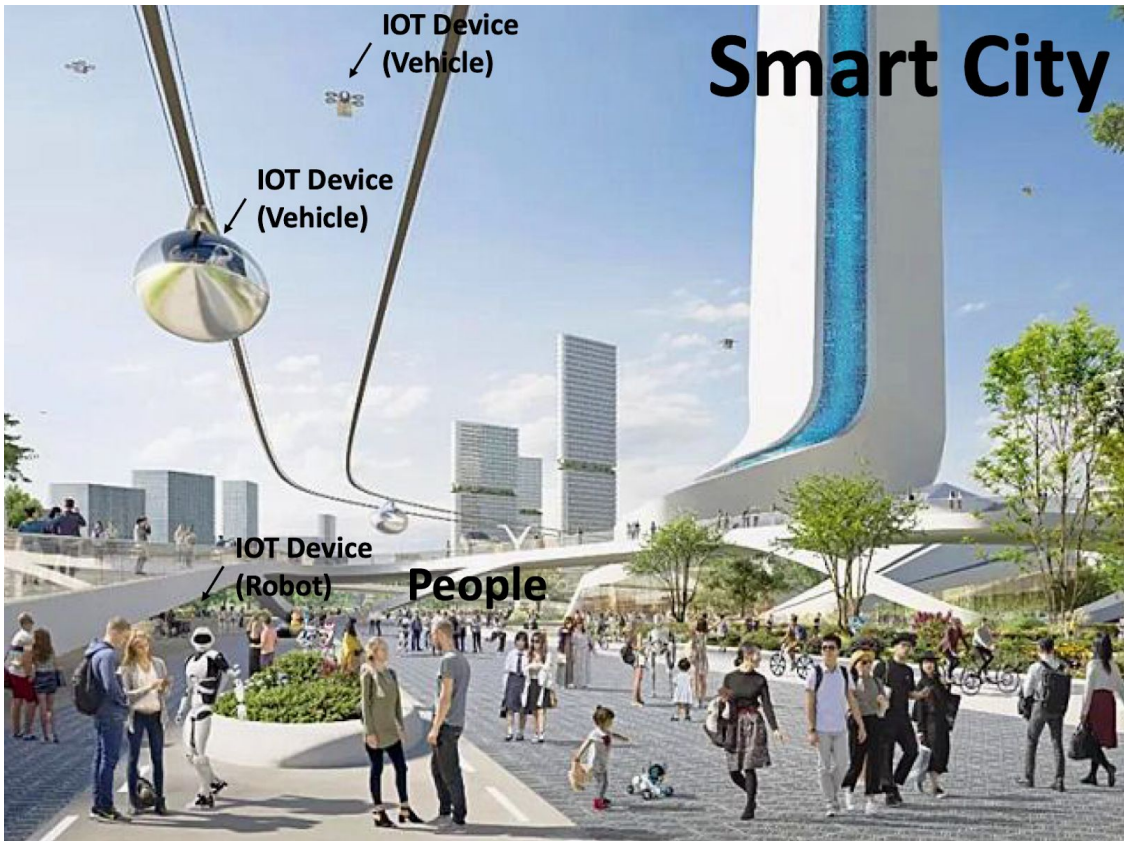
Date: 9/15/2020

Author: Loi Cheng

Reviewer(s): Andrew Pham, Chris Sorenson

Introduction

The Smart City Software System will fully automate the city of the future. Smart City allows city administrators to fully automate a city through AI-powered Internet of Things (IoT) devices, including cameras, microphones, robots, and other devices. Sensors monitor the location of persons within the city. Robot Assistants help residents and visitors, clean the city, and respond to emergencies. Some of the devices are controlled automatically, and all devices are able to interact with people through a voice interface.



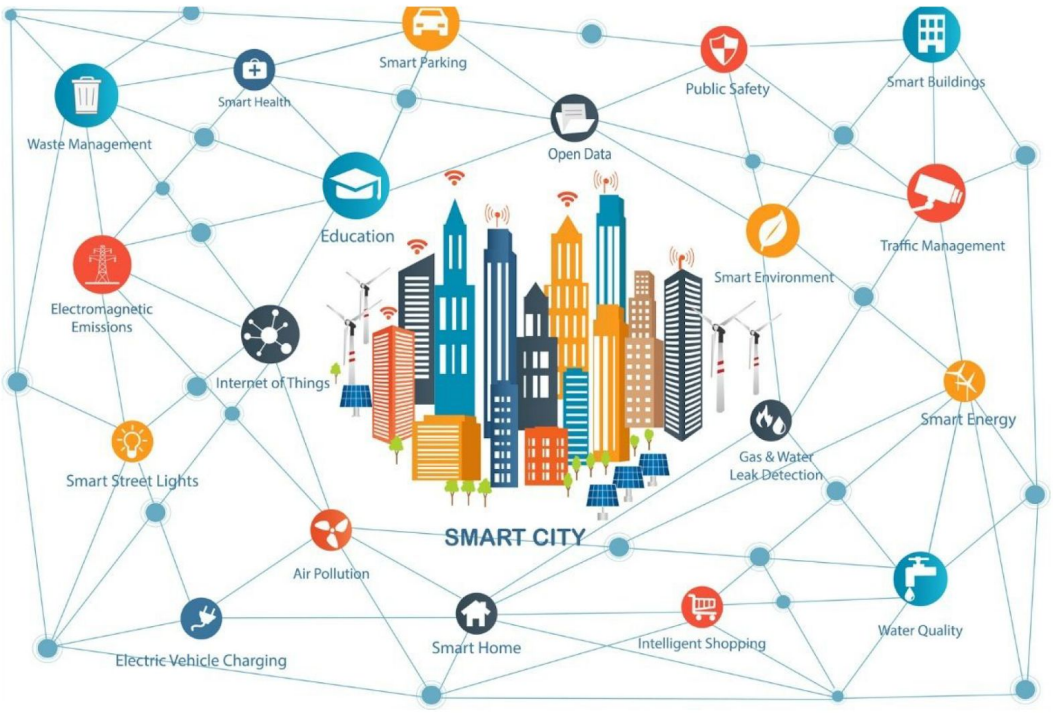
Caption: People and Devices in the Smart City

Overview

This design specifies the implementation of a Smart City Service. The Smart City Model Service is responsible for managing the domain entities of the Smart City System. Domain entities include the city, people, and IoT devices, including street signs, information kiosks, street lights, parking spaces, public servant robots, and vehicles. The Smart City Model Service provides an API for interacting with those objects. The API supports querying the state of the entities, as well as updating the state.

The Smart City improves the quality of life of its people. Examples of improvements include:

- Connected vehicles efficiency moves between destinations, reduces wait and transport times, improves transportation efficiency
- Smart signs and Info Kiosk brings important information to nearby people, improving direct public communications
- Smart parking spaces directs vehicles to them when empty, or directs them to other empty spaces when full
- Robots provide assistance where needed
- Sensors monitors the health of overall inhabitants and acts accordingly in emergencies



Caption: The Smart City System Interconnects the City Inhabitants with the Internet of Things

Requirements

This section defines the requirements for the Smart City Model Service.
The Smart City Model Service is primarily responsible for managing the state of the City domain objects including:

- City
- People
    - Resident
    - Visitor
- Iot Devices
    - Street Sign
    - Information Kiosk
    - Street Light
    - Robot
    - Parking Space
    - Vehicle
        - Bus
        - Car

City

The City is used to model a city instance. Note that the Smart City system is a cloud based service and must be able to manage multiple Cities. A City has the following attributes:

- Globally unique identifier (e.g. city-1)
- Name (e.g. “Cambridge, MA”)
- Multiple people, either residents or visitors
- Multiple IoT Devices
- A blockchain account for receiving and sending money
- Location (lat, long)
- Radius which specifies the area encompassed by the city.

Person

Persons model the people that live in the city. A Person can be either a Resident or Visitor. Residents are well known persons, where visitors are anonymous. Both Residents and Visitors are assigned a unique person id.

Attributes of Residents include:

- Globally unique id
- Biometric Id
- Name of resident
- The phone number of the resident

- The Role of the resident (adult, child, or public administrator)
- Blockchain Account Address
- Location (lat/long)

Attributes of Visitor include:

- Globally unique id
- Biometric Id
- Location (lat/long)

Iot Devices

IoT Devices are the internet connected components of the Smart City. All IoT devices have the following attributes:

- A globally unique id
- Location(lat/long)
- Current status (ready, offline)
- Enabled (on/off)
- And the latest event emitted from the device

All IoT devices have the following sensors:

Input

- Microphone
- Camera
- Thermometer
- CO2 Meter

Output

- Speaker

The Sensors generate events that are processed by the Virtual IoT Devices. Events have a type, action, and an optional subject. For example, the microphone may generate an event {microphone,“where is the nearest bus stop?”, resident:alice}. Note that the microphone is able to convert speech to text. Or the Camera may generate the event {camera,”person walking”, resident:bob}. Note that the microphone and camera sensors use AI to automatically identify the subject person. The CO2 Sensor may generate the following event {CO2, “400ppm”}, similarly, the Thermometer may report the current ambient temperature {thermometer, “88F”}, or the temperature of an individual {thermometer, “98.6F”, “jane”}.

In addition to input sensors, all IoT devices include a speaker for generating output speech, allowing the IoT devices to interact with Residents and Guests using natural language.

The following section describes the types of IoT devices:

Street Sign

A street sign is an IoT device that provides information for vehicles. It is able to alter the text displayed on the sign. For example, it can dynamically adjust the speed limit, or warn about an accident ahead.

Information Kiosk

The Information Kiosk helps residents and visitors. It is able to interact with Persons, though speech and displaying images. For example the Kiosk can display a map and help provide directions. The Kiosk can also support purchasing tickets for concerts and other events.

Street Light

The Street Light is an IoT device for illuminating the city. The Street Light is able to adjust its brightness.

Robot

Robots act as public servants. Robots are mobile and can respond to commands from Residents and Visitors. For example, helping to carry groceries. They can also asset in emergencies, for example putting out a fire.

Parking Space

A Parking Space is an IoT device able to detect the presence of a vehicle. A parking space has an hourly rate which is charged to the account associated with the vehicle.

Vehicle

Vehicles are mobile IoT Devices that are used for giving rides to Residents and Visitors. Vehicles can be either a Bus or a Car. Vehicles have a maximum rider capacity. Both Cars and Busses are autonomous. Riding in a Bus or Car is free for Visitors, but requires a fee for Residents.

Smart City Model Service

The Smart City Model Service provides a top level Service interface for provisioning cities. It also supports controlling the City's IoT devices. Any external entity that wants to interact with the Smart City Model Service, must access it through the public API of the Model Service.

The Model Service provides a service interface for managing the state of the Cities.

The API supports commands for

- Defining the City configuration
- Showing the City configuration
- Updating the City configuration
- Creating/Simulating sensor events
- Sending command messages to IoT Devices
- Accessing IoT State and events
- Monitoring and supporting Residents and Visitors

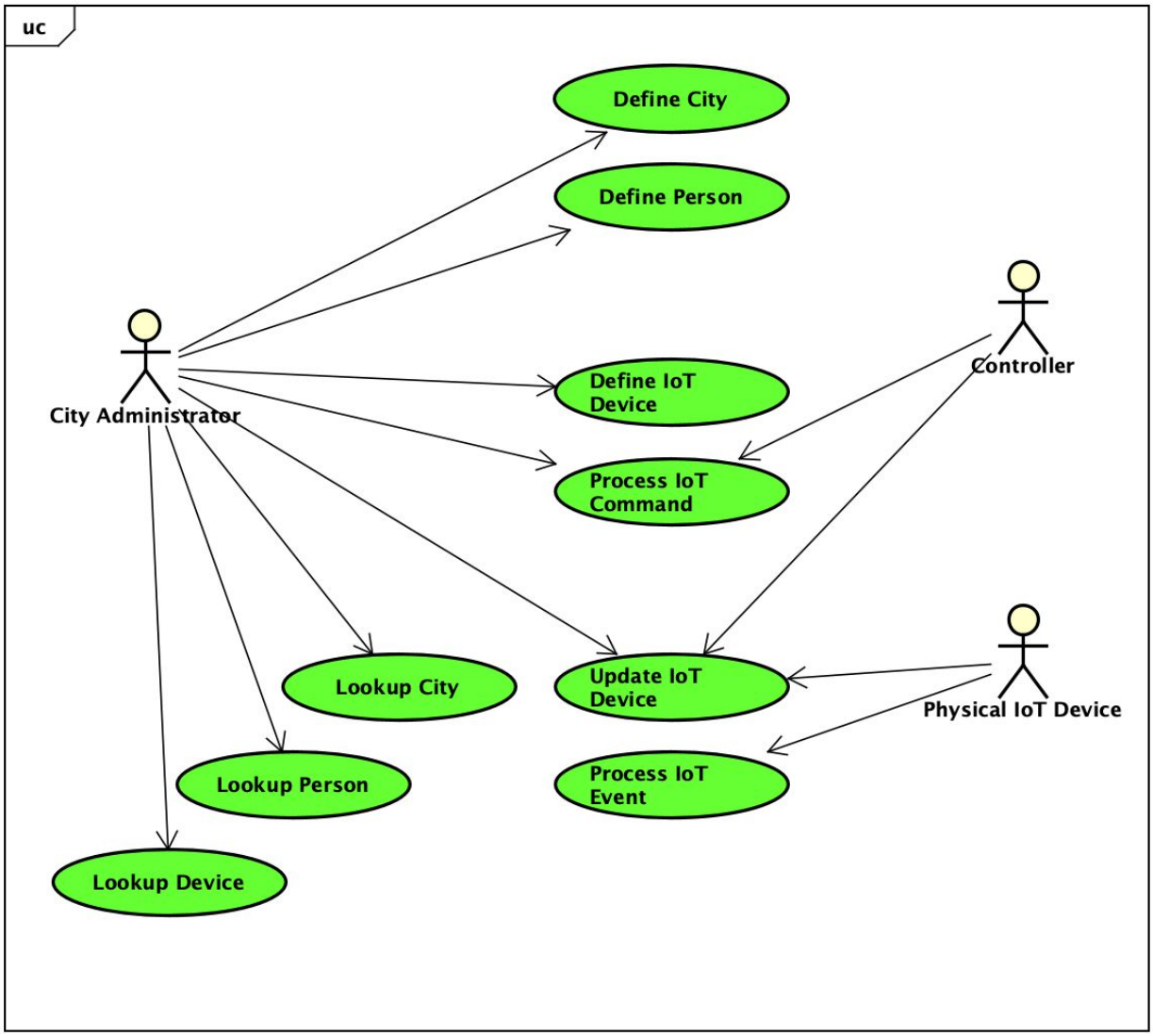
All API methods should include an auth_token parameter that will be used later to support access control.

Command API

The Smart City Model Service supports a Command Line Interface (CLI) for configuring Cities and generating simulated sensor events. The commands can be listed in a file to provide a configuration script. The CLI should use the service interface to implement the commands.

Use Cases

The following use case diagram documents the high-level use cases supported by the Smart City Software System.



Caption: UML Use case diagram with Smart City actors and use cases.

There are 5 types of actors:

- City Administrator
- Person
- Physical IoT Device
- Controller
- Simulator

City Administrators are responsible for configuring the smart city. This includes defining the city, provisioning the IoT devices, and setting up identities for the residents of the city.

Persons are the residents and guests that inhabit the city. Maximizing the person's experience is very important. Residents and visitors can interact with the various IoT devices and request Services.

Physical IoT devices monitor the city. For example, one type of IoT device, the Robot Public Servant, maintains the city, including cleaning the city, assisting people, and responding to emergencies. IoT devices are fully automated and also respond to requests from persons and the Smart City Controller.

Caption: One type of IoT Device, the Public Servant Robot

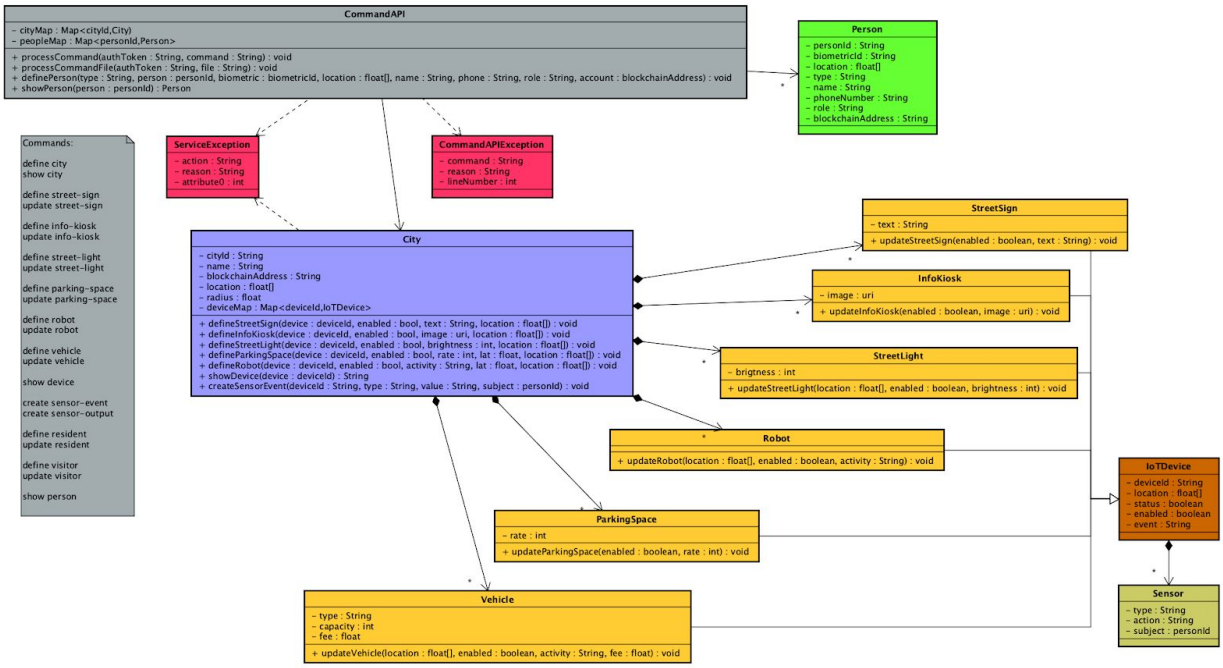
The Smart City Controller provides the overall management for the city. The Controller monitors the city and people through IoT devices, processing events, and generating control Commands. The Controller monitors the location and status of all persons and manages the IoT devices around them either proactively or in response to voice commands. For example, when a person asks for help, the Controller will automatically send a robot public servant to assist the person.

The Simulator supports testing the Smart City system by providing a source for the sensor events in place of using actual physical IoT Devices.

Implementation

Class Diagram

The following class diagram defines the Ledger implementation classes contained within the package “cscie97.smartcity.model”.



Class Dictionary

CommandAPI

The CommandAPI is a utility class for feeding the city a set of operations, using command syntax. The command syntax specification follows:

City Commands

```
# Define a city
define city <city_id> name <name> account <address> lat <float> long <float> radius <float>

# Show the details of a city. Print out the details of the city including the id, name, account,
location, people, and IoT devices.
show city <city_id>
```

Device Commands

```
# Define a street sign
define street-sign <city_id>:<device_id> lat <float> long <float> enabled (true|false) text <text>

# update a street sign
update street-sign <city_id>:<device_id> [enabled (true|false)] [text <text>]

# Define an information kiosk
define info-kiosk <city_id>:<device_id> lat <float> long <float> enabled (true|false) image <uri>

# Update an information kiosk
update info-kiosk <city_id>:<device_id> [enabled (true|false)] [image <uri>]

# Define a street light
define street-light <city_id>:<device_id> lat <float> long <float> enabled (true|false) brightness <int>

# Update a street light
update street-light <city_id>:<device_id> [enabled (true|false)] [brightness<int>]

# Define a parking space
define parking-space <city_id>:<device_id> lat <float> long <float> enabled(true|false) rate <int>

# Update a parking space
update parking-space <city_id>:<device_id> [enabled (true|false)] [rate<int>]

# Define a robot
define robot <city_id>:<device_id> lat <float> long <float> enabled(true|false) activity <string>
```

Update a robot
update robot <city_id>:<device_id> [lat <float> long <float>] [enabled(true|false)] [activity <string>]

Define a vehicle
define vehicle <city_id>:<device_id> lat <float> long <float> enabled(true|false) type (bus|car) activity <string> capacity <int> fee <int>

Update a vehicle
update vehicle <city_id>:<device_id> [lat <float> long <float>] [enabled(true|false)] [activity <string>] [fee <int>]

Show the details of a device, if device id is omitted, show details for all devices within the city
show device <city_id>[:<device_id>]

Simulate a device sensor event
create sensor-event <city_id>[:<device_id>] type (microphone|camera|thermometer|co2meter) value <string> [subject <person_id>]

Send a device output
create sensor-output <city_id>[:<device_id>] type (speaker) value <string>

Person Commands
Define a new Resident
define resident <person_id> name <name> bio-metric <string> phone <phone_number> role (adult|child|administrator) lat <lat> long <long> account <account_address>

Update a Resident
update resident <person_id> [name <name>] [bio-metric <string>] [phone<phone_number>] [role (adult|child|administrator)] [lat <lat> long <long>] [account <account_address>]

Define a new Visitor
define visitor <person_id> bio-metric <string> lat <lat> long <long>

Update a Visitor
update visitor <person_id> [bio-metric <string>] [lat <lat> long <long>]

Show the details of the person
show person <person_id>

Association Name	Type	Description
cityMap	Map<cityId,City>	A map of all created cities and their cityId

Method Name	Signature	Description
processCommand	(authToken:string, command:string):void	Process a single command. The output of the command is formatted and displayed to stdout. Throw a CommandProcessorException on error. The authToken should be verified before processing.
processCommandFile	(authToken:string, commandFile:string):void	Process a set of commands provided within the given commandFile. Throw a CommandProcessorException on error. The authToken should be verified before processing.
definePerson	(type : String, person : personId, biometric : biometricId, location : float[], name : String, phone : String, role : String, account : blockchainAddress) : void	Define a new person. For type:visitor, these are not required: name, phone, role, blockchain address
showPerson	(person : personId) : void	Show the details of the person

IoTDevice

The IoTDevice class represents an IoT device.

IoT Devices are the internet connected components of the Smart City. All IoT devices have the following attributes:

- A globally unique id
- Location(lat/long)
- Current status (ready, offline)
- Enabled (on/off)
- And the latest event emitted from the device

All IoT devices have the following input sensors:

- Microphone
- Camera
- Thermometer
- CO2 Meter

The Sensors generate events that are processed by the Virtual IoT Devices. Events have a type, action, and an optional subject. For example, the microphone may generate an event {microphone,“where is the nearest bus stop?”, resident:alice}. Note that the microphone is able to convert speech to text. Or the Camera may generate the event {camera,”person walking”, resident:bob}. Note that the microphone and camera sensors use AI to automatically identify the subject person. The CO2 Sensor may generate the following event {CO2, “400ppm”}, similarly, the Thermometer may report the current ambient temperature {thermometer, “88F”}, or the temperature of an individual {thermometer, “98.6F”, “jane”}.

In addition to input sensors, all IoT devices include a speaker for generating output speech, allowing the IoT devices to interact with Residents and Guests using natural language.

Property Name	**Type**	**Description**
deviceId	string	The device id
location	float[]	The latitude and longitude location of the device
status	boolean	Current status (ready, offline)
enabled	boolean	on/off
event	String	The latest event emitted from the device

Association Name	Type	Description
speaker	Sensor	The device speaker
microphone	Sensor	The device microphone
camera	Sensor	The device camera
thermometer	Sensor	The device thermometer
co2meter	Sensor	The device CO2 meter

StreetSign

The StreetSign is a type of an IoT device. It extends the IoTDevice class

A street sign is an IoT device that provides information for vehicles. It is able to alter the text displayed on the sign. For example, it can dynamically adjust the speed limit, or warn about an accident ahead.

Property Name	Type	Description
text	String	The text displayed on the sign

InfoKiosk

The InfoKiosk is an information kiosk, and is a type of an IoT device. It extends the IoTDevice class.

The Information Kiosk helps residents and visitors. It is able to interact with Persons, though speech and displaying images. For example the Kiosk can display a map and help provide directions. The Kiosk can also support purchasing tickets for concerts and other events.

Property Name	Type	Description
image	uri	A pointer to the image to be displayed

StreetLight

The StreetLight is a type of an IoT device. It extends the IoTDevice class.

The Street Light is an IoT device for illuminating the city. The Street Light is able to adjust its brightness.

Property Name	Type	Description

brightness	int	The brightness of the light, from 0(min) to 100(max)

Robot

The Robot is a type of an IoT device. It extends the IoTDevice class.

Robots act as public servants. Robots are mobile and can respond to commands from Residents and Visitors. For example, helping to carry groceries. They can also asset in emergencies, for example putting out a fire.

The robot inherits all properties from the IOTDevice class.

ParkingSpace

The ParkingSpace is a type of an IoT device. It extends the IoTDevice class.

A Parking Space is an IoT device able to detect the presence of a vehicle. A parking space has an hourly rate which is charged to the account associated with the vehicle.

Property Name	**Type**	**Description**
rate	int	The hourly rate charged by the the parking space

Vehicle

The vehicle is a type of an IoT device. It extends the IoTDevice class. All vehicles are autonomous, and owned by the city.

Vehicles are mobile IoT Devices that are used for giving rides to Residents and Visitors. Vehicles can be either a Bus or a Car. Vehicles have a maximum rider capacity. Both Cars and Busses are autonomous. Riding in a Bus or Car is free for Visitors, but requires a fee for Residents

Property Name	**Type**	**Description**
type	String	The type of vehicle (bus or car)
capacity	int	The maximum number of passengers
fee	float	The amount charged for each seat per mile

Sensor

IoT devices are able to generate sound output through speakers.

The Sensors generate events that are processed by the Virtual IoT Devices. Events have a type, action, and an optional subject. For example, the microphone may generate an event {microphone,“where is the nearest bus stop?”, resident:alice}.

Property Name	Type	Description
type	String	The type of sensor (eg microphone)
action	String	An action specific to the type of sensor (eg “where is the nearest bus stop?”)
subject	personId	An optional person the action pertains to

Person

Persons model the people that live in the city. A Person can be either a Resident or Visitor. Residents are well known persons, where visitors are anonymous. Both Residents and Visitors are assigned a unique person id.

Property Name	Type	Description
type	String	The type of Person (resident or visitor)
biometricId	String	Unique id of the person
location	float[]	Latitude and longitude location of person
name	String	For type:residient is the name of the person. For visitor it is null
phoneNumber	String	For type:residient is the phone number of the person. For visitor it is null

role	String	Role of the resident (adult, child, or public administrator). For visitor it is null
blockchainAddress	String	Blockchain address of the resident. For visitor it is null

City

The City class provides a top level service interface for provisioning cities. It also supports controlling the City's IoT devices. Any external entity that wants to interact with the City, must access it through the CommandAPI.

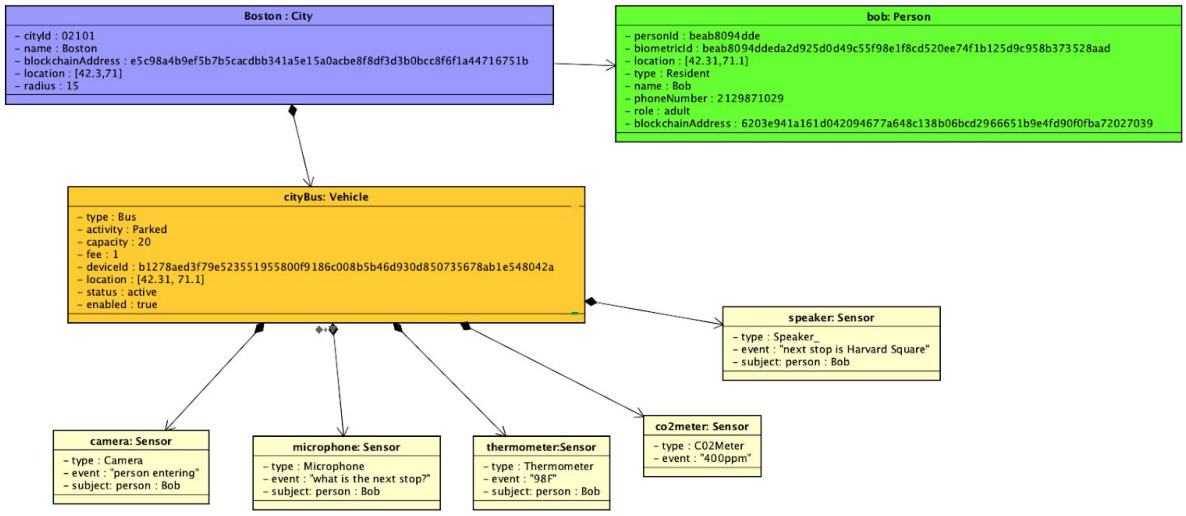
Property Name	**Type**	**Description**
cityId	String	Unique id of the city
name	String	Name of the city
blockchainAddress	String	blockchain address of the city
location	float[]	Latitude and longitude location of the city
radius	float[]	Radius of the area encompassed by the city

Association Name	**Type**	**Description**
peopleMap	Map<personId,Person>	A map of the person id and the associated Person
deviceMap	Map<deviceId,IoTDevice>	A map of the device id and the associated device

Method Name	Signature	Description
defineStreetSign	(device : deviceId, enabled : bool, text : String, location : float[]) : void	Define a new street sign, and add it to the device map
defineInfoKiosk	(device : deviceId, enabled : bool, image : uri, location : float[]) : void	Define a new info kiosk, and add it to the device map
defineStreetLight	(device : deviceId, enabled : bool, brightness : int, location : float[]) : void	Define a new street light, and add it to the device map
defineParkingSpace	(device : deviceId, enabled : bool, rate : int, lat : float, location : float[]) : void	Define a new parking space, and add it to the device map
defineRobot	(device : deviceId, enabled : bool, activity : String, lat : float, location : float[]) : void	Define a new robot, and add it to the device map
showDevice	(device : deviceId) : String	Show the details of a device, if device id is omitted, show details for all devices within the city
createSensorEvent	(deviceId : String, type : String, value : String, subject : personId) : void	Simulate a device sensor event. The subject is optional

Implementation Details

The following simplified instance diagram shows a City with 1 person and 1 device.



The core component is the City class. The City class provides an API for interacting with the City and implements the API methods that manage the people and devices.

Exception Handling

There are 2 types of exceptions to handle: ServiceException, and CommandException.

ServiceException

The ServiceException is returned from the methods in response to a specific error. It captures the action that was attempted and the reason for the failure. Service exceptions should be caught by the Command Exception.

Property Name	**Type**	**Description**
action	string	action that was performed (e.g., “update robot ”)
reason	string	Reason for the exception (e.g. “robot not found”).

CommandException

The CommandException is returned from the CommandAPI methods in response to an error condition. The CommandException captures the command that was attempted and the reason for the failure. In the case where commands are read from a file, the line number of the command should be included in the exception.

Property Name	Type	Description
command	string	Command that was performed (e.g., “update robot ”)
reason	string	Reason for the exception (e.g. “robot not found”).
lineNumber	int	The line number of the command in the input file.

Testing

Implement a TestDriver class that implements a main() method. The main() method can call these methods:

CommandAPI.processCommandFile(authToken: String, file:String)
CommandAPI.processCommandFile(authToken: String)

The main method can receive a command file, or allow a user to enter commands in a console if no file is specified. The TestDriver class should be defined within the package “cscie97.smartcity.test”.

Risks

Since this is a system dealing with people and devices, it will be subject to hackers who will attempt to undermine it. City administrators are required to have an authorization token to use the city service.