SWEN3185 Software Modeling

PP2 Project Proposal

Vehicle Tracking System

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Description/Overview of the System

With an escalating level of crime throughout Jamaica, the need for protecting one's personal property has become paramount, and as a result many security companies have put in place safety protocols and measures to aid in the safeguarding of these valuables; namely vehicle tracking systems. As much as they provide security, there are still faults within these types of systems and due to their critical nature, it is imperative that a system of this nature be examined in great detail to understand the possible faults. For the purpose of this modelling we will be focused on the vehicle's tracking devices, its communication with cellular networks and its interaction with a monitoring system for the tracking device.

It is widely known that vehicle tracking systems give their users a sense of security and peace of mind by providing its users with the whereabouts as well as various states as it relates to the vehicle. The main purpose of the system is to provide real-time location tracking of the vehicle. To implement this system, a SIM card enabled tracking device is configured by a security company's representative and attached to the engine of the desired vehicle to be monitored. The tracking device is solely powered by the vehicle's battery and a geofence as it relates to the vehicle is initialised by a security company's representative. The tracking device will be able to communicate with different cell towers and be identified by transmitting the device's IMEI number and SIM card's serial number. This technology falls under the topic of 'geolocation', which is defined as the process of determining the physical location of a device or user based on data from GPS, Wi-Fi, cellular network or other sources of location data; as it relates to this project we will relate it to cell towers.

The geofence, as it relates to the tracking system, is as a location defined by a set of points that form a polygon which the installers of the tracking device are responsible for creating. This location specified is limited to a particular area in Jamaica and is unique to every tracking device. In this system, the geofence itself consists of three to five points and multiple geofences for locations such as homes, offices, and other desired areas may be created.

The fail safe in terms of the device is a magnetic switch located inside the tracking device that only the person installing the device knows about. This magnetic switch has to be unlocked or disengaged before the device is removed for repairs or replacement. In the case where the switch is not unlocked and the tracking device is tampered with, a signal will be sent out to the system administrators. The owner of the vehicle and the installation mechanic are the only people that know where the tracking device is located in the vehicle.

The communication between the cell towers and the tracking devices are dependent on the communication signal type. Each tracking device will support one of 3 signal types (i.e. None, 3G, LTE and 5G where None refers to no communication type).

With this, the latency of signals, which is determined by weather conditions, being sent and received to and from the cell tower will determine the reliability of the tracking device and its packets. It is assumed that 5G provides the greatest strength and as a result, has the greatest transmission speed. Each tracking device's signal strength will be determined by signal bars. These bars range from Level 1 to Level 4, with Level 4 being the greatest in strength. The condition of the signal is called experience. For example, you could have Level 4 bars but the communication type Edge resulted in a poor connection.

Once the tracking device is considered 'out-of-range' to any nearby cell towers, it may use Bluetooth Low Energy (BLE) to communicate with other nearby devices which have BLE capabilities. These nearby devices may act as communicators on behalf of the tracking device to nearby cell towers/cellular networks allowing the encrypted tracking data to be transmitted to the cell towers and eventually the monitoring centre.

The key components of the system as they relate to the tracking device are:

- to send and receive automated signals to cell towers at different time intervals which will facilitate real time location tracking, these time intervals may be recognized as few, often, and persistent
- to send a user prompted signal via a 'button' to cell towers
- to be configured for user specified alerts which may include but are not limited to:
    - vehicle battery status; which may be 'on', or 'off'
    - vehicle ignition status; which may be 'on', or 'off'
    - vehicle movement as it relates to vehicle's geofence; which may be inside or outside
- the weather of the location which may be recognized as good, suitable, bad, and unsuitable.

The key components of the system as they relate to the monitoring system are:

- to assign levels of signals received from cell towers that may be recognized as three states in relation to location: in-range, suitable and out-of-range
- to receive a signal from cell towers that may be user prompted

Mathematical Concepts

In specifying the system, three mathematical concepts that are considered crucial are Graph Theory, State Machines and Set Theory.

Graph Theory may be used to keep a record of how a vehicle moves from point A to point B on a map. It may also aid in the calculation of the shortest distance or path for best use of resources.

As it relates to State Machines, these may be used to acknowledge the different states of the tracking device, the vehicle (its position and engine and battery as it relates

to the vehicle), location as it relates to cell towers and weather conditions as these all have changing states in the system. These aspects of the system all have an initial and an end state which is affected after a change due to an event within the system. For example, a tracking device's state may change from 'off' to 'on' when the vehicle's engine state experience's a change from 'off' to 'on' as well.

Lastly, Set Theory may be recognized in the system by defining and managing the vehicles being tracked and users who have access to the system. Set theory will introduce the ability to investigate different operations between the relations as it relates to unions, intersections and differences.

Abstractions

Focusing on the most essential parts of the system, abstractions were made to better understand the essential characteristics. It is recognized that in the vehicle tracking system, the tracking device sends and receives signals at different time intervals to various cell towers once it is powered by the battery of the vehicle. The tracking device may be in-range, suitable-range and out-of-range in relation to its location to a cell tower. The tracking device may also interact with various types of weather when in use; good, suitable, bad, and unsuitable. These weather conditions may affect the reliability and quality of service of the tracking device. We will define the kind of weather conditions that are associated with each type of weather in a table below:

Weather Type	**Weather Condition**
Good	Sunny, Clear
Suitable	Light Rain, Cloudy
Bad	Heavy Rain, Windy, Foggy
Unsuitable	Lightning and Thunderstorms

As it relates to the geofence, the tracking device may give alerts based on its entrance and exit of the geofence. This geofence is recognized as a base location for the tracking device. The tracking device may also send signals based on the vehicle's engine status.

Additionally, there are two types of users who take advantage of the vehicle tracking system;commercial and private users. These users may have more than one tracking device associated with them and as such commercial users may have access to a magnitude of tracking devices.

Constraints

To ensure that the integrity of the system is kept when modelling, restrictions and limitations of the system must be acknowledged. As it relates to the vehicle tracker device, it must first be configured correctly by a system representative to be considered usable; the vehicle tracker device must be attached to the vehicle's engine and battery, and must have a network registered SIM card.

For the tracking device to serve its purpose, the battery of the vehicle must be powered on and provide sufficient power for the device. The tracking device must also be connected to the vehicle's engine in order to send and receive signals as it relates to the vehicle engine's state of 'on' or 'off'.

As it relates to location, the tracking device must be 'in-range' or 'suitable' location to a cell tower to be able to send and receive signals to and from the cell tower(s). If the tracking device is out-of-range to a cell tower, it will not be able to send and receive signals to and from the cell tower(s).

The weather of the location of the tracking device must also be considered 'good' or 'suitable' to be able to send and receive signals to and from the cell tower(s). If the weather of the location of the tracking device is 'bad', the tracking device may not be able to send and receive signals to and from the cell tower(s). If the weather of the location of the tracking device is 'unsuitable', the tracking device will not be able to send and receive any signals to and from the cell tower(s).

As it relates to the geofence, one must have been established by a company representative. The tracking device must cross the geofence in order to send and/or receive a signal related to the geofence.

Properties for Investigation

With modelling this system, there is aim to investigate the properties of correctness, safety and security.

As it relates to correctness of the system, the geolocation and sending and receiving of signals to and from the cell towers to the tracking device will be investigated. This will ensure that the system operates as intended and satisfies the specification based on the abstractions noted. The quality and consistency of the data the system provides and well as how effectively the system achieves its goals will be recognized here.

In regards to the safety of the specification, this is crucial as it prevents the system from undesired behaviour. This will be examined by investigation into the constraints and the interaction of the users and entities of the system; such as tracking devices and users(customers). For example, an undesired behaviour of the system may be the inaccuracy of the geolocation data provided by the tracking device.

Lastly, the security will be recognized by ensuring that the sensitive data of the system (as it may relate to user information, vehicle data, tracking device data etc) is kept secure. This is also another crucial attribute to be investigated in the context of formal specification techniques to ensure that the model represents the guarding against potential threats such as unauthorised access, data manipulation or denial-of-service attacks..

Benefits Gained from System Specification

After completion of modelling the system, the benefits that can be achieved by the use of a formal specification technique are:

- an increased system quality and dependability,
- a better understanding of the vehicle tracking system and its limitations,
- a lower likelihood risk of errors in the system,
- early inaccuracy and consistency detection,
- and an improvement of knowledge, communication and precision as it relates to the needs, abstractions, and constraints of an intricate system.

Parts of the System to be Modelled

To limit the scope of the project, there are a few assumptions that we will highlight, namely:

- All signals sent and received as well as real-time tracking of all vehicles will be monitored by the Monitoring Centre.
- The installation of the tracking device is done correctly and by a certified technician
- The tracking device's geographical locations are within the boundaries of Jamaica.
- The tracking device’s geofence is static and does not move overtime as it is related to a specific location; such as a home, or office.
- The system will generate alerts when the vehicle deviates from its geofence
- All cell towers support all communication signal types
- That all other devices may communicate with the tracking device via BLE once the tracking device is out of range
- That tracking devices that support LTE will also be able to communicate in the other communication types

With these assumptions in mind, the key components of the system we would like to model in Alloy would include different scenarios of the tracking device and its relation and interaction to the vehicle, communication with cell towers and the

designated geofences. Additionally, we will consider how external factors, such as weather conditions, may impact communication between the tracking device and cell towers.

Constraints and Invariants

Facts	Description in English	Not Overconstrained	Properly Specified

fact EachVehicleUniqueEngine{
all disj v1, v2: Vehicle | v1.engine != v2.engine
}
	Every vehicle has a unique engine	Every vehicle will have one and only one engine	An instance will be generated showing for all vehicles, only one unique engine is associated

fact EachTrackingDeviceLinkedToAVehicle{
all t1: TrackingDevice | t1 in Vehicle.tracker
}
	Each tracking device must be linked to a vehicle	Every tracking device will be linked to one and only one vehicle	An instance will be generated showing for all vehicles, only one unique tracking device associated

fact AllTrackingDeviceHaveCommunicationType{
all t1: TrackingDevice | one t1.communicationType
}
	All tracking devices must have a communicationType to a cell tower	Every tracking device will have one and only one communication type associated to itself	An instance where the tracking device shows a communication type associated with it when connected to a tower

fact AllTrackingDeviceHaveOneRange{
all t1: TrackingDevice | one t1.range
}
	All tracking devices must have one range to a cell tower	Every tracking device will have one and only one range with a cell tower	An instance where for every tracking device, a relationship depicting a range between it and the cell tower

fact NoCommunicationTypeIfTrackingDeviceOff { all t1: TrackingDevice | t1.status = Off implies no t1.communicationType	If a tracking device is off then it should not have a communicationTy	Every tracking device when off will not show a communication type	An instance where for every tracking device once off there is no communication type linked to it

} 	pe to the cell tower		
fact NoCommunicationTypeIfTrackingDeviceOff { all t1: TrackingDevice, veh: Vehicle	veh.engine.status = Off implies t1.status = Off } 	If a vehicle engine status is off, so is tracking device	Every vehicle once off will not show a status for the tracking device	An instance where the vehicle will show status off and tracking device off as well

fact CommunicationRelationToLocationOutOfRange {
 	
  all t: TrackingDevice
	dom[t.range] = Level_0 implies dom[t.communicationType] = None and t.experience = Poor
	  all t: TrackingDevice
		dom[t.communicationType] = None implies dom[t.range] = Level_0
		  all t: TrackingDevice
			dom[t.range] = Level_1 implies t.experience = Poor
			  all t: TrackingDevice
				dom[t.range] = Level_2 and dom[t.communicationType] = EDGE implies t.experience = Poor
				  all t: TrackingDevice
					dom[t.range] = Level_2 and dom[t.communicationType] = Com_3G implies t.experience = Okay
					  all t: TrackingDevice
						dom[t.range] = Level_2 and dom[t.communicationType] = Com_4G implies t.experience = Okay
						  all t: TrackingDevice
							dom[t.range] = Level_2 and dom[t.communicationType] = LTE implies t.experience = Okay
							  all t: TrackingDevice
								dom[t.range] = Level_3 and	A tracking device must only communicate with the cell tower in a specific type of communication based on its location to the cell tower i.e. Best - 4G and LTE, Acceptable - 3G, 4G, and LTE, Low - 3G and Edge and Out_Of_Range - None	Then the system may allow for a tracking device to communicate with a cell tower in an inappropriate communication type based on its location. This could result in poor communication quality, data loss, and other issues.	The system will ensure that a tracking device must only communicate with the cell tower in a specific type of communication based on its location to the cell tower. Specifically, the system will enforce the communication capability of a tracking device based on its location and categorize it as Best - 4G and LTE, Acceptable - 3G, 4G, and LTE, Low - 3G and Edge, and Out_Of_Range - None. This will ensure appropriate communication quality and reduce the likelihood of data loss and other communication issues.

dom[t.communicationType] = EDGE implies t.experience = Okay all t: TrackingDevice | dom[t.range] = Level_3 and dom[t.communicationType] = Com_3G implies t.experience = Good all t: TrackingDevice | dom[t.range] = Level_3 and dom[t.communicationType] = Com_4G implies t.experience = Good all t: TrackingDevice | dom[t.range] = Level_3 and dom[t.communicationType] = LTE implies t.experience = Excellent all t: TrackingDevice | dom[t.range] = Level_4 and dom[t.communicationType] = EDGE implies t.experience = Okay all t: TrackingDevice | dom[t.range] = Level_4 and dom[t.communicationType] = Com_3G implies t.experience = Good all t: TrackingDevice | dom[t.range] = Level_4 and dom[t.communicationType] = Com_4G implies t.experience = Excellent all t: TrackingDevice | dom[t.range] = Level_4 and dom[t.communicationType] = LTE implies t.experience = Excellent }			

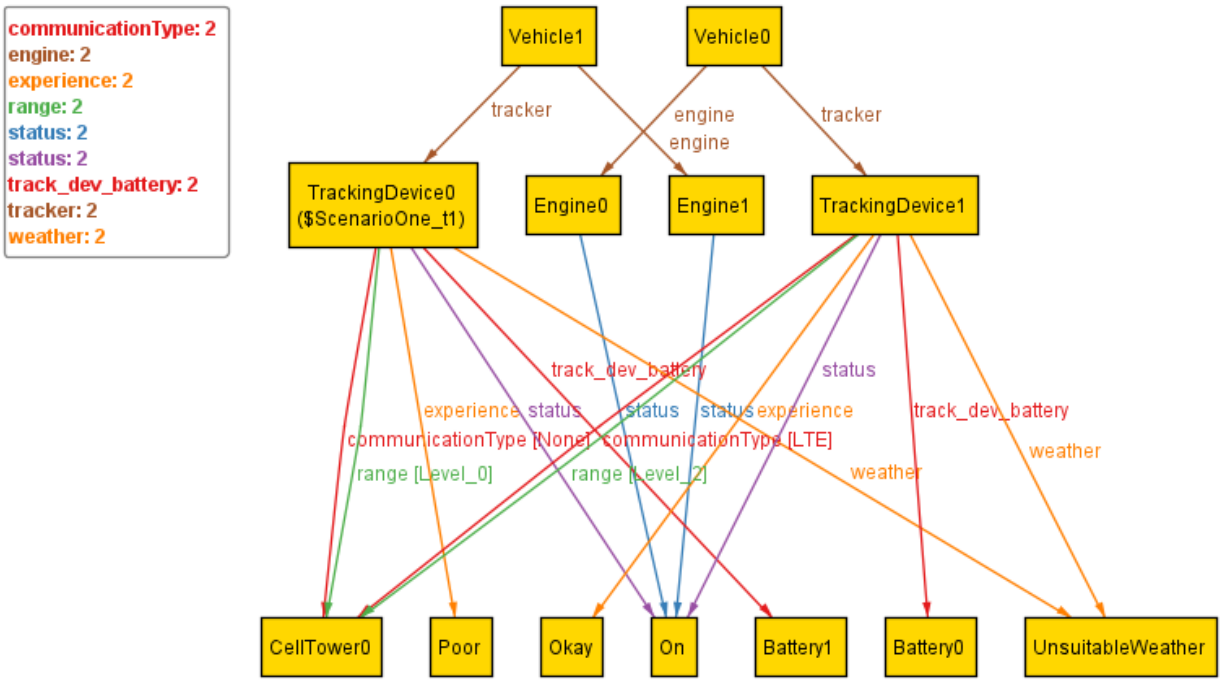
fact uniqueTrackerBattery{
all disj t1, t2: TrackingDevice | t1.track_dev_battery != t2.track_dev_battery
}
	Each tracker has a unique battery	System should allow for multiple trackers to exist, each with a unique battery.	The system will ensure that each tracker in the system has a unique battery assigned to it. This means that if we were to look at the set of all batteries used by the system, there would be no duplicates. Additionally, the

			system would not allow for a tracker to be assigned a battery that is already in use by another tracker
fact OnlyCommunicateWithOtherDeviceWhenOutofRange{ --changed due to updated code all t1: TrackingDevice, oth: OtherDevice, loc: Location, cell: CellTower | loc -> oth in t1.connection implies None -> cell = t1.communicationType }	The tracking device may only communicate with a 'other device' if /the tracking device is Out_Of_Range to a cell tower.	The system may allow for a tracking device to communicate with an 'other device' even if it is not out of range of a cell tower. This could result in unnecessary communication and potentially interfere with other communications within the system	The system will ensure that a tracking device can only communicate with an 'other device' if it is out of range of a cell tower. This means that the connection between the tracking device and the 'other device' (denoted by 'loc -> oth in t1.connection') should only be true if the connection between None and a cell tower (denoted by 'None -> cell = t1.communicationType ') is also true. In other words, if the tracking device is in range of a cell tower, it should not be able to communicate with an 'other device', and if it is out of range of a cell tower, it should only be able to communicate with an 'other device'.

System Instances

Scenario 1

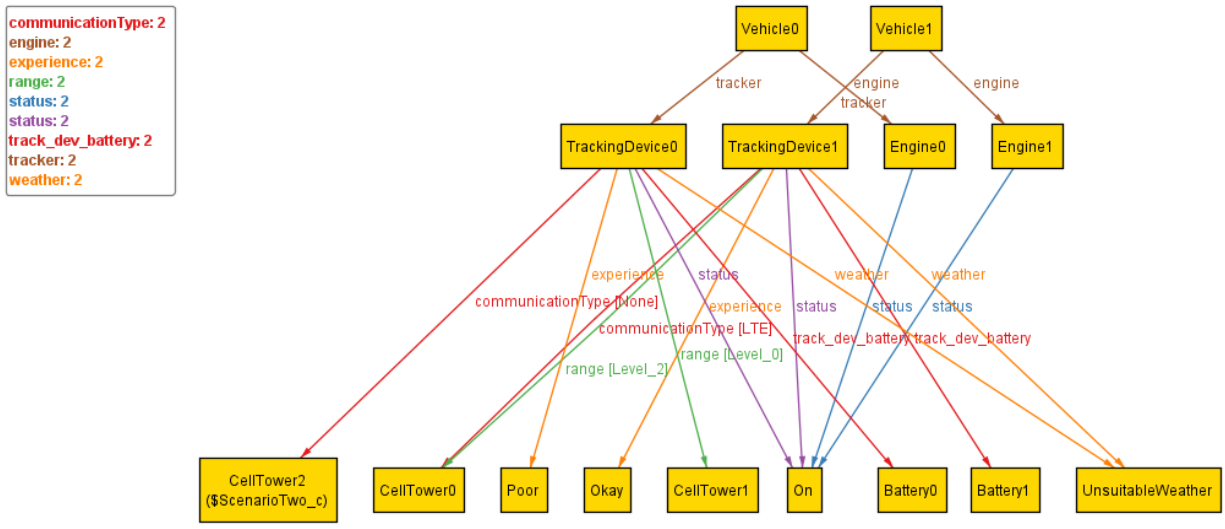
The tracking device is far away from the cell tower which means there are no CommunicationTypes available and automatically create a connection with another device.



In the instance generated above, we have two vehicles with their own engines that are represented in the system. They both individually have their own tracking device which both have their own individual batteries as well as engines. Both engines have a status of “on”. Both devices are within the cell tower’s 0 and 1 range. Tracking device 0 ‘s location currently has unsuitable weather and the experience is poor which has resulted in a communication type of none. Tracking device 1’s location also has unsuitable weather but the experience is okay resulting in a communication type of okay. This is an accurate depiction of what should happen in the system as LTE communication type can work in okay weather conditions.

Scenario 2

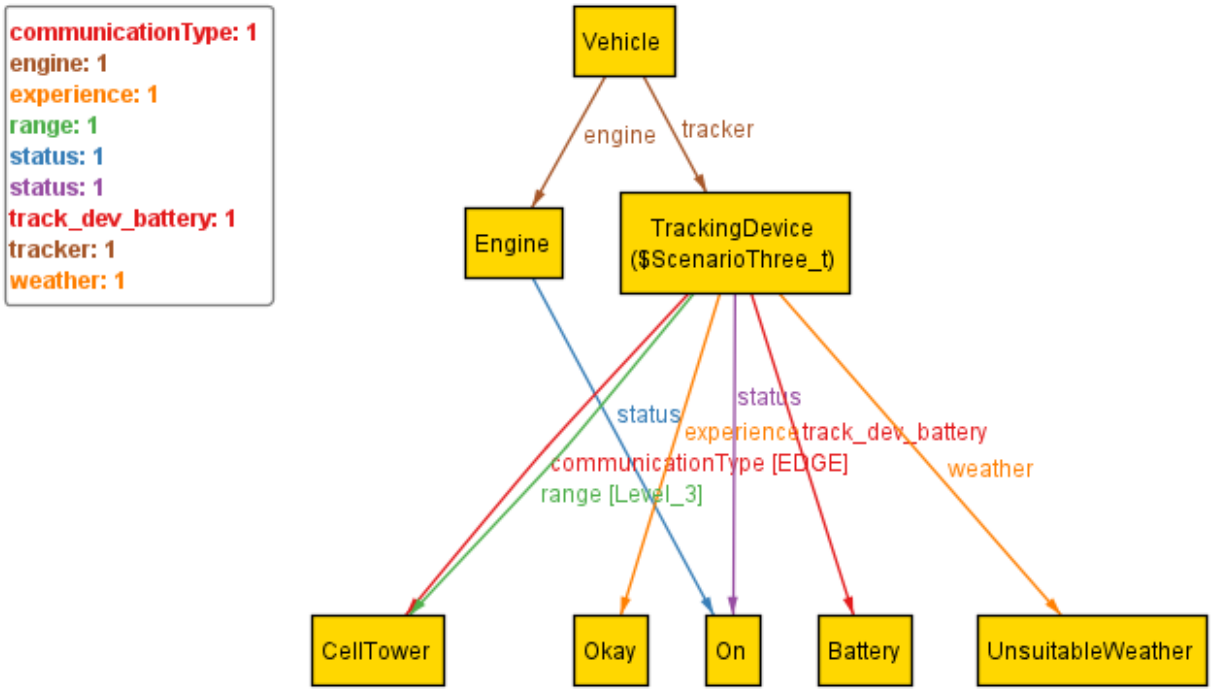
Multiple cell towers in a geographic location and at least one tower must be able to identify that a tracking device is near a cell tower.



In the instance generated above it shows two vehicles, each with their own tracking device. Tracking device 1 is connected to cell tower 0 and it's communication type is LTE and tracking device 0 is connected to cell tower 2 with a communication type none and it is also connected to cell tower 1. The weather is unsuitable in both cases but the experience for tracking device 1 is okay whereas the experience for tracking device 0 is poor. The range at which tracking device 0 is connected to cell tower 1 is level 0 (no bars) and the range at which tracking device is connected to cell tower 0 is level 2 (2 bars).

Scenario 3

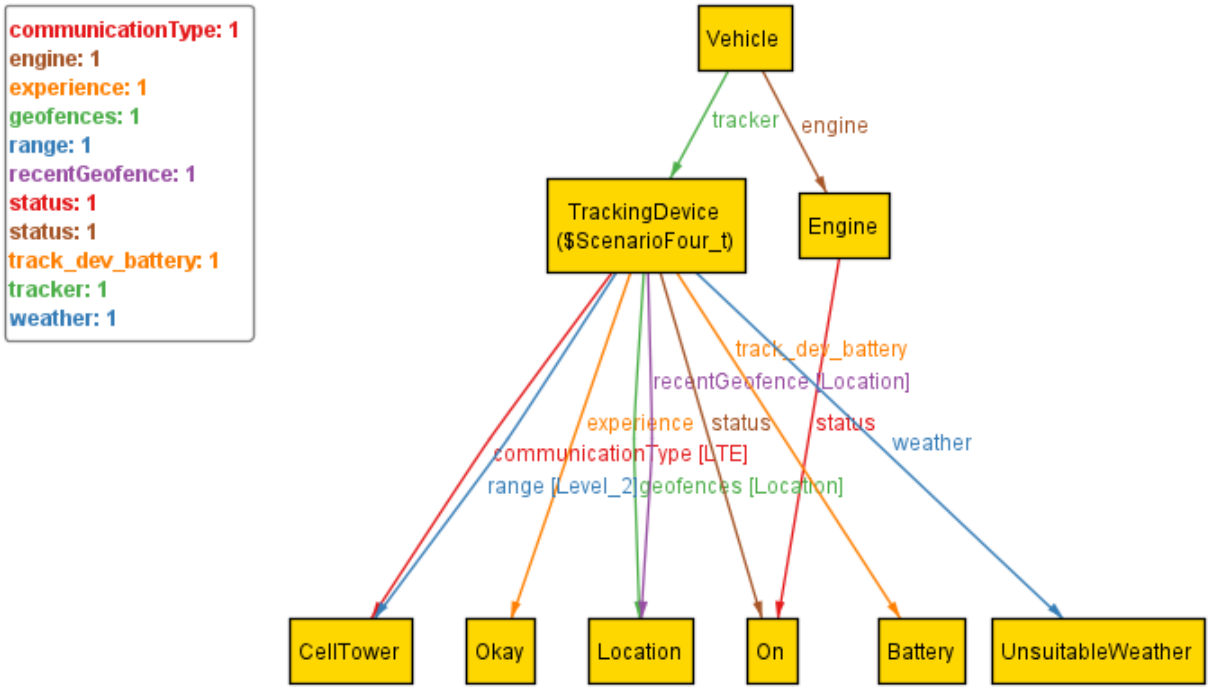
The tracking device is near a cell tower, but the weather condition is bad resulting in poor or okay experience



In the above scenario, a tracking device is near a cell tower shown by its range of Level_3, it is also affected by the weather of UnsuitableWeather. The combination of these factors cause the experience of the communication of the tracking device to be ‘Okay’ (though it also may be ‘Poor’). Additionally, in order for this communication to exist the Vehicle’s Engine must also be on and the Tracking Device’s status must also be on.

Scenario 4

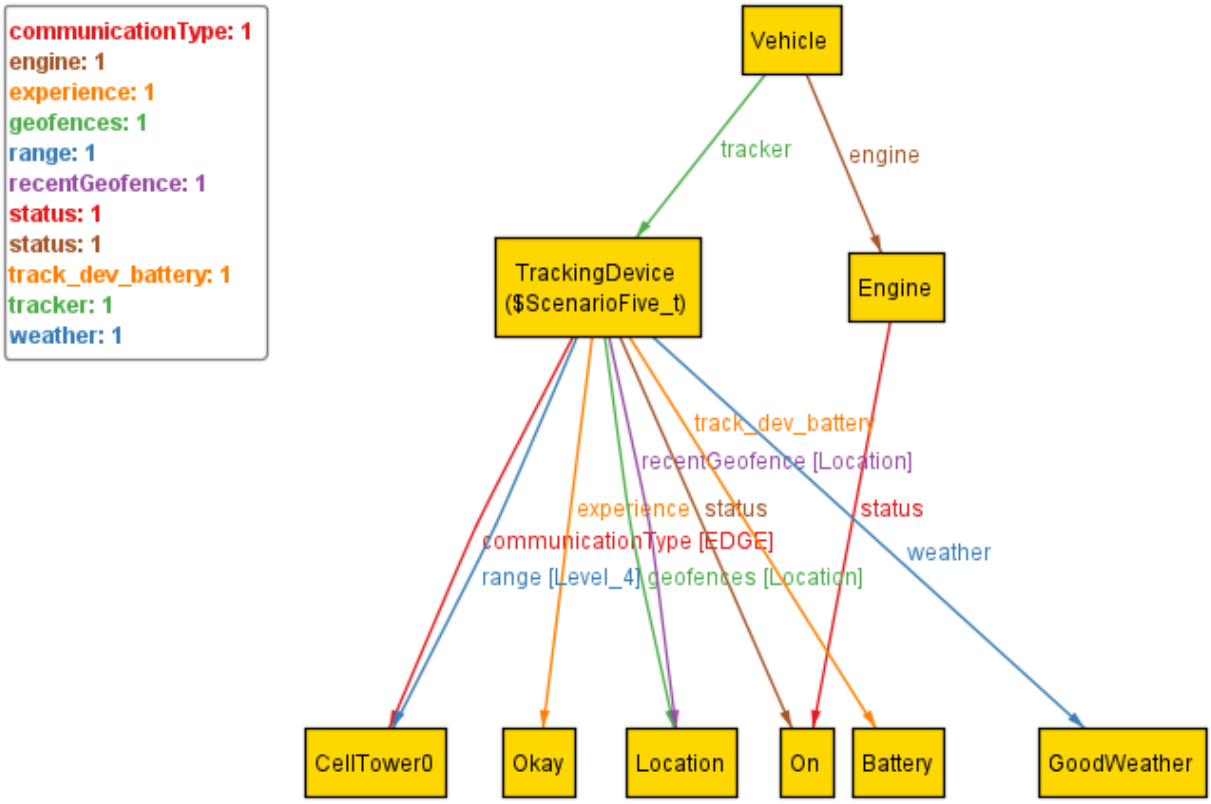
Vehicle has left geofence and should have an alert



This scenario depicts a vehicle that has its own tracker and engine. This engine is on and the tracking device is on as well. The range the tracking device has with the cell tower is of Level 2 and as a result the experience is okay. The communication type is LTE. The vehicle has currently left its geofence and is not showing a recording of the last geofence it obtained.

Scenario 5

The tracking device is near a cell tower, outside of it's geofence, weather condition is good and the tracking device supports LTE



In the scenario above, there is one vehicle with a tracking device. The tracking device is communicating with cell tower 0 with communication type being EDGE. The range is level 4 which means that its at its strongest (4 bars) indicating it is near to a cell tower in good weather. Good weather meaning there a re little to no hindrances in communication between the tracking device and cell tower.