India

Automated Illegal Parking Management LoRaWAN™ Whitepaper

Release Date: 29 November 2018

Author: Kush Mishra, CTO of SenRa Tech Pvt. Ltd.

Table of Contents

Figures

Tables

1 Introduction

The Government of India has started the Smart City Mission as an urban renewal and retrofitting program to develop 100 cities across India leveraging cutting edge technology which will create a more scalable and sustainable environment for an ever-growing population. This initiative will bring forward many advancements to cities to include smart infrastructure, smart governance, smart utilities, and smart citizens.

This white paper makes an effort to demonstrate how smart technologies based on LoRaWAN, can solve critical problems typical to India and also contribute to the overall Smart Cities Mission leveraging creative analytics, cloud-based data processing, and cost-effective infrastructure and solutions.

2 Audience

The audience for this whitepaper is Smart City decision makers, Community Leaders, System Integrators, Service and Solution Providers, Enterprises, and others intending to contribute to India's Smart Cities Mission by leveraging Low-Power Wide-Area Network (LPWAN) technology. This whitepaper will describe the technical capabilities of LPWAN technologies with focus on the LoRaWAN™ protocol and how it has successfully been deployed in a live Proof of Concept (PoC) using Smart Parking Sensors to reduce illegal parking and improve traffic congestion for one of India's Smart Cities.

3 India's Illegal Parking Challenges

Alongside a rapid growth in population, India is seeing a steady rise in income of an average middle-class household. This rapid growth, coupled with cultural shifts such as small nuclear families, dual income households etc. has led to a rapid increase in density of motor vehicles per household. This is putting an additional strain on the existing parking infrastructure of the already over-congested cities.

As a natural alternative, most car owners, in the absence of parking spots, choose to park on temporary spots such as road side. Often these parking spots are marked illegal by the city authorities. It is estimated that on any working day, over 40% of the urban road area is taken up by parked cars.

Several cities including Delhi, Chandigarh and Pune have taken steps towards framing a parking policy to reduce parking pressure and congestion on roads and public spaces. The efforts however, fail to balance the supply of parking spaces with efforts to reduce the overall demand for parking.

There are several problems with these conventional parking policies:

1. There is an unsustainable pressure on the available land for a wasteful use.
2. Minimal pricing for street parking irrespective of the demand
3. Illegal encroachment of public spaces and walkways
4. Restricted access for emergency services in congested areas

Even the planned smart parking management solutions have not been found to yield expected results due to choosing sub-optimal technologies. The parking sensors themselves are sometimes based on localized wireless area networks which suffer from low battery life and high maintenance costs. Instead of collecting and storing the occupancy and traffic data from these sensors and using them for advanced analytics, the data is merely displayed on an LED panel to determine vacant and occupied status. Features like parking reservation and route planning according to nearest available parking spots are not available in a centralized fashion.

4 Introduction to Smart Parking Solution

Smart Parking Solutions across the world aim to leverage smart IoT technologies to manage city's organized and unorganized car parking lots in an efficient manner. The solution is based on camera based sensors and/or surface mount sensors for on-street parking and off-street parking slots. Parking Sensor are primarily used to detect the occupancy of the parking bay and communicate back the parking occupancy status to the local processing system/controller. LED display units are used for communicating the occupancy status and other relevant information at the parking entry/exit gates. In addition, entry/exits are coordinated using an arrangement of boom barriers, ticket dispensers and PoS machines to collect payments.

Although cities in India have made efforts towards such smart parking management systems, an overwhelming majority of cities still suffer from unorganized and illegal car parking due to a lack of enforcement methods and effective selection of sensor and communication technologies.

5 Leveraging Smart Things

In recent years, the "Internet of Things" (IoT) has come to the fore front of discussion as an innovative and sustainable approach in addressing Smart City initiatives such as smart parking. Many cities have begun leveraging "Smart Things" to transform their way of thinking and living in a smarter and more digital way. Smart Things are typically comprised of sensors, devices, gateways, and other intelligent hardware which have the ability to send information in a smart way to a system where processing of the data takes place. Most of the time these Smart Things send their data wirelessly to the Internet or "Cloud" for processing. Although wireless solutions have existed for over 25 years in certain industries, the way data is sent, collected, stored, analyzed, and then viewed has evolved over time and has been one of the main driving factors of today's Smart Things. One key area which cities have begun to focus on in order to support the data sent from these Smart Things is the communication infrastructure and the associated technologies which provide the means to communicate this ever so important data.

6 Low-Power Wide-Area Networks

To address the communication infrastructure element, several wireless technologies were analyzed to determine which provided cities a low cost, long range, and low power consumption solution. It was decided that Low-Power Wide-Area Network solutions provided what was necessary to deploy city wide solutions with minimal impact on financial commitments, infrastructure, maintenance, and management of deployed solutions. LPWAN technology also was suited for solutions which only require devices to send small data over a wide area while maintaining battery life over many years. This made LPWAN more interesting in comparison to the other wireless network protocols like Bluetooth, RFID, cellular M2M, and ZigBee, shown below with regards to bandwidth and range capability.

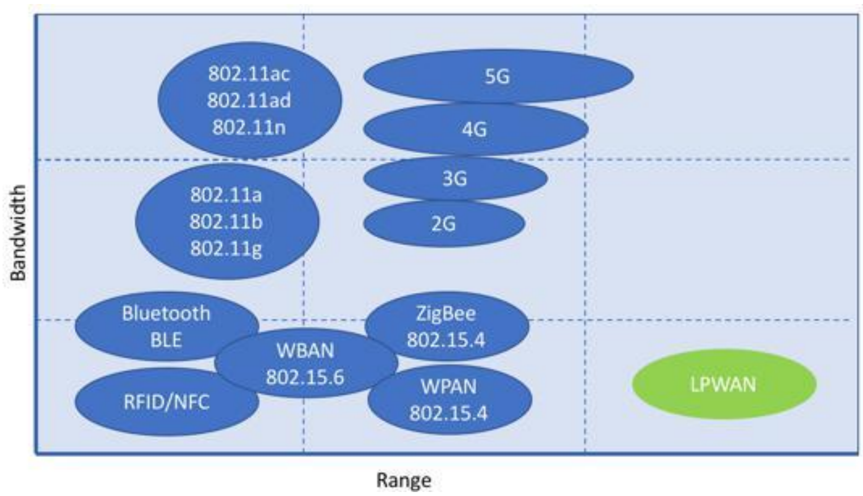

Figure 1: Wireless Network Protocol Comparisons

6.1 LPWAN Comparisons

The next step in selection of the correct communication protocol was to conduct a more detailed review of the leading LPWAN technologies to determine the most suitable option for smart cities within the Indian market. Based on Table 1 comparisons, as well as current city policies and requirements driving the decision making, several capabilities were looked at during this process.

Smart City Requirements	LoRaWAN™	SigFox	Ingenu	LTE NB-IoT	Cellular	LAN (Wi-Fi / BLE)
Standards	Yes, Open (Lora Alliance)	No, Proprietary	No, Proprietary	Yes	Yes	Yes
Built in Security	Yes	No	Yes	TBD	No	Varies
Bi-Directional Communication	Yes	Limited	Yes	Yes	Yes	Yes
Interference	Unlicensed 865MHz	Unlicensed 865MHz	Unlicensed 2.4GHz	Licensed Regionalized	Licensed Regionalized	Unlicensed 2.4GHz

Table 1: LPWAN Technology Comparisons

Standards, security, communication capabilities, and spectrum inference were some of the main factors which lead the selection of LoRaWAN™ as the technology which would be used during this Proof of Concept. By implementing Low-Power Wide-area Networks based on the LoRaWAN™ protocol, solutions such as smart water metering allow cities to reduce operational cost dramatically while still obtaining the necessary data to make better water management decisions. LoRaWAN™ infrastructure enables smart water solutions while maintaining the integrity of the data and reliability of the communication all while reducing the overall impact on the processes involved in managing smart water infrastructures.

6.2 LoRaWAN™ Protocol

LoRa® is the physical layer or the wireless modulation utilized to create the long-range communication link. Many legacy wireless systems use frequency shifting keying (FSK) modulation as the physical layer because it is a very efficient modulation for achieving low power. LoRa® is based on chirp spread spectrum modulation, which maintains the same low power characteristics as FSK modulation but significantly increases the communication range. Chirp spread spectrum has been used in military and space communication for decades due to the long communication distances that can be achieved and robustness to interference, but LoRa® is the first low cost implementation for commercial usage.

LoRaWAN™ defines the communication protocol and system architecture for the network while the LoRa® physical layer enables the long-range communication link. The protocol and network architecture have the most influence in determining the battery lifetime of a device, the network capacity, the quality of service, the security, and the variety of applications served by the network.

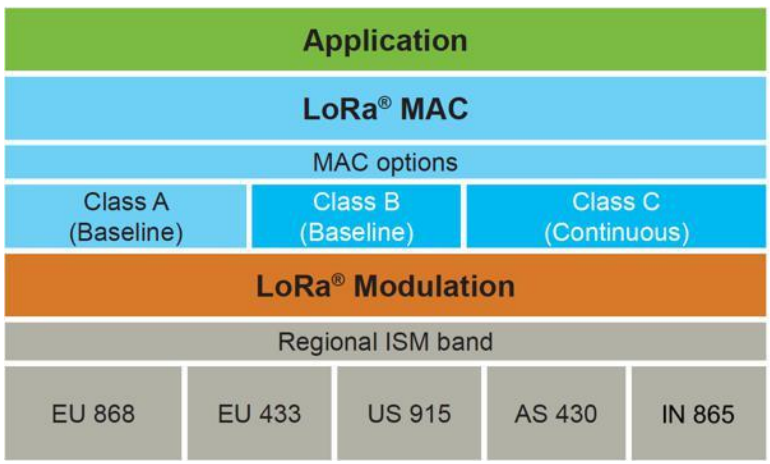

Figure 2: LoRa® Communication Protocol

6.3 LoRaWAN™ Architecture

Many existing deployed networks utilize a mesh network architecture. In a mesh network, the individual end-nodes forward the information of other nodes to increase the communication range and cell size of the network. While this increases the range, it also adds complexity, reduces network capacity, and reduces battery lifetime as nodes receive and forward information from other nodes that is likely irrelevant for them. Long range star architecture makes the most sense for preserving battery lifetime when long-range connectivity can be achieved.

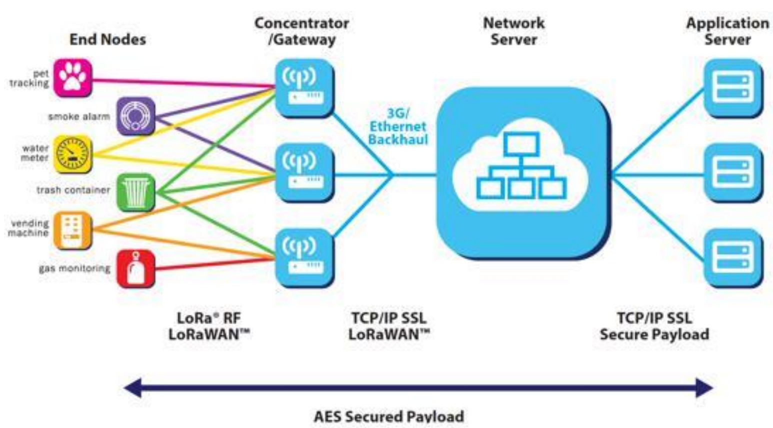

Figure 3: LoRaWAN™ Network Architecture

In a LoRaWAN™ network nodes are not associated with a specific gateway. Instead, data transmitted by a node is typically received by multiple gateways. Each gateway will forward the received packet from the end node to the cloud-based network server via some backhaul (either cellular, Ethernet, satellite, or Wi-Fi). The intelligence and complexity are pushed to the network server, which manages the network and will filter redundant received packets, perform security checks, schedule acknowledgments through the optimal gateway, and perform adaptive data rate, etc. If a node is mobile or moving, there is no handover needed from gateway to gateway which addresses other major target application verticals for IoT.

The benefit of a LoRaWAN™ network is immense considering the fact that a city-wide network or an area-based network will be able to provide multiple services to the citizens such as smart street lights, smart parking sensors, smart environmental sensors, smart metering on a single network deployment. This also allows the city administrators to have a clear insight on the device and network management without worrying about managing multiple protocols and layers of data streams from a host of varied technologies. LoRaWAN™ is the only technology which caters to smart city requirements and is currently available for commercial deployments.

6.4 LoRaWAN™ India 865-867 MHz ISM Band

Based on the Government of India Ministry of Communications and Information Technology (Wireless Planning and Coordination Wing) notification which took place on the 10th January 2007, the use of low power equipment in the frequency 865-867 MHz is exempt from licensing requirements. This is critical to Smart City decision makers as current tenders and requests for proposals are highlighting that use of the unlicensed ISM band is preferred and sometimes required. Based on this information, The LoRa Alliance™, an open, nonprofit association comprised of over 500 companies to date, defined in the LoRaWAN™ regional specifications 1.0.2 that development for the India region should use the unlicensed spectrum defined by the Indian government (865-867 MHz).

7 Automated Illegal Parking Management

The illegal car parking situation in India requires a conscious effort towards improving the situation not only on part of the citizens but also from the enforcement bodies. This means at the very minimum, identifying and acknowledging the problem as a prevailing menace. As part of the Amritsar Automated Illegal Parking Management project, our first steps were to educate the city officials about how the problem of Illegal car parking can be solved using smart technology. The second step was to demonstrate the solution after having city official buy-in. We deployed 6 LoRaWAN™ enabled smart parking sensors, our LoRaWAN™ network for connectivity, and streamed the data to our IoT analytics platform and mobile application, providing the city with an end-to-end smart parking solution.

With all the challenges present in India's traffic and parking management, we felt this solution could solve problems and have an amazing ROI for the city. After 2 months of data collection, we have been able to determine the ROI is approximately 10 times the cost of the actual solution.

7.1 Illegal Parking Site Locations

This Proof of Concept was conducted in Amritsar, a city located in the northern part of India. The city selected 6 sites where they requested to install LoRaWAN™ enabled Smart Parking Sensors. Site locations for deployed sensors are illustrated in Figure 4.

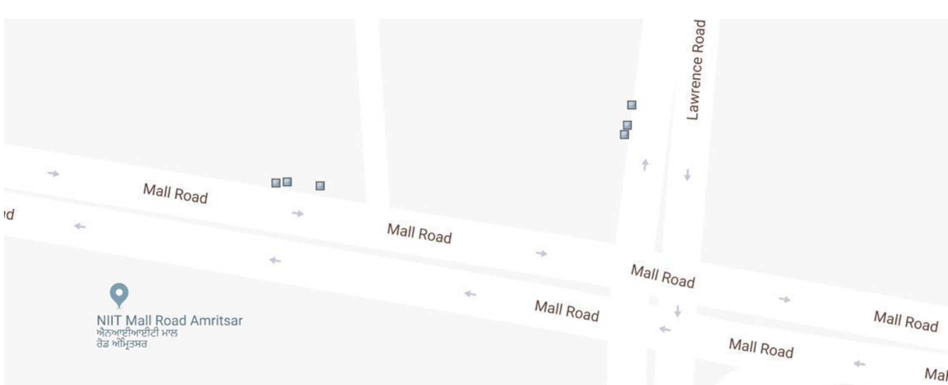

Figure 4: Smart Parking Sensor Site Locations (grey squares)

7.2 Network Deployment

Based on the site locations provided, a survey was conducted of the area to determine where the LoRaWAN™ network infrastructure would be deployed to provide reliable, stable connectivity. Things that were looked at included accessibility of the site, power availability, backhaul capabilities, elevation above sea-level and ground-level, obstructions and clear line of site. Two sites were selected for this network deployment. Based on elevation above ground, gateways being deployed, and other factors mentioned above, a green field planning of the LoRaWAN™ RF propagation was done and is illustrated below in Figure 5 and Figure 6.

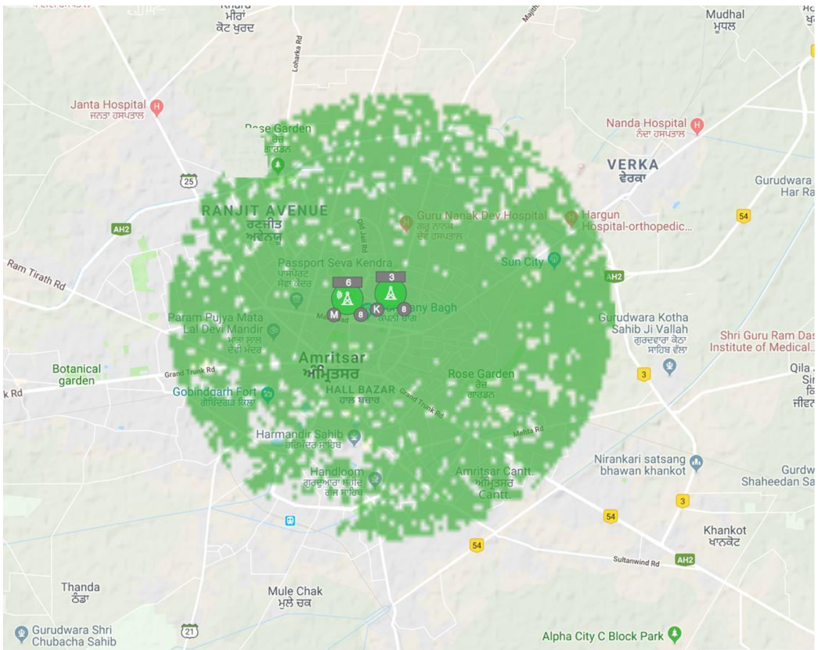

Figure 5: LoRaWAN™ Gateway Site 1 (micro-cell gateway)

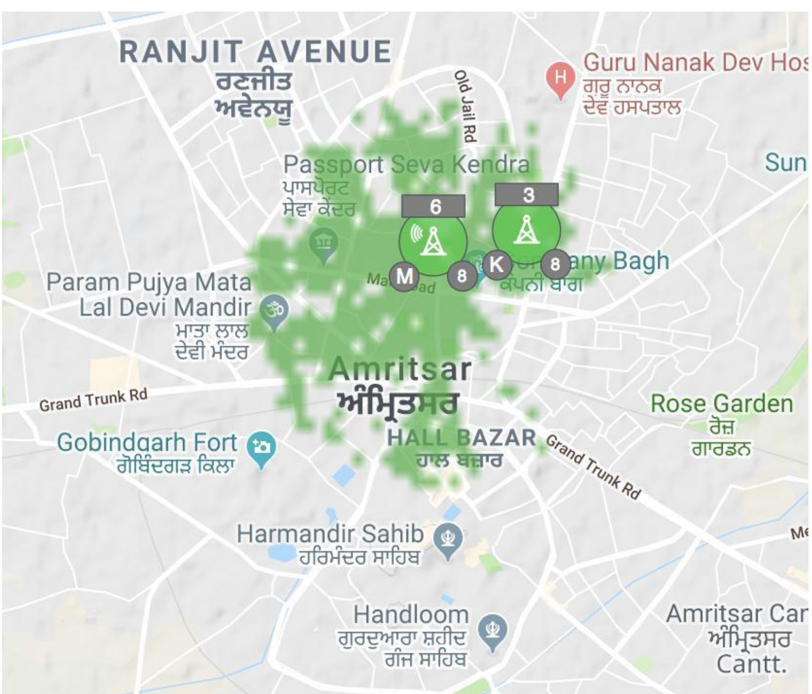

Figure 6: LoRaWAN™ Gateway Site 2 (pico-cell gateway)

The following table provides details of both sites and their coverage achievements. Note while the overall coverage at the parking sensor sites were ensured by an Outdoor Micro-cell Gateway installed at Gateway Site 1 shown above, an additional Gateway Site 2 was installed with an Indoor Pico-cell Gateway to increase the density of coverage

Site	Height	Elevation	Coverage (Radius)
1	100 ft.	757 ft.	2.5 miles
2	15 ft.	761 ft.	1 mile

Table 2: Gateway Site Coverage Details

We were able to achieve the following key benefits from this deployment topography:

- greater resilience to interference
- lower power consumption
- ensure the devices can leverage the benefit of ADR to increase battery life

Since the devices were installed in the ground, there was a significant risk of interference and loss of signal due to a significant obstruction from ground and nearby concrete inside the Fresnel zone. Therefore, the antenna polarization for both gateway and end devices was oriented vertically to ensure optimal reception. Also, a site survey was performed to verify the RF signal did not exceed -90dBm when no vehicle was parked on top of the parking sensors.

7.3 Smart Parking Sensor - Device Selection

After careful evaluation of Parking sensor vendors, a suitable OEM was chosen as preferred supplier for the devices to solve the most mission-critical aspects of parking management: accurate and real- time vehicle detection. The sensor uses very accurate magnetic sensing system and sophisticated vehicle detection algorithms that accurately detect the presence or absence of a car in a given parking space even in dense urban environments which are typically prone to magnetic interference. The device includes a built in LoRa™ radio that communicates to a SenRa gateway with complete adherence to LoRaWAN™ technical and regional specifications.

One of the most important criteria for device selection was ability to be installed in a *deploy and forget* scenario. This means the device should have an ultra-low power consumption and several years of battery life. It is ensured by the LoRaWAN™ MAC protocol and the device software algorithms that the device can deliver up to 10 years of battery life, and is stable over temperature fluctuations, even in harsh environments.

7.4 Installation Procedure

The Illegal parking spots allocated to SenRa by Amritsar Smart City were located on the on main streets which are in parallel to the traffic flow.

Prior to installation each sensor's unique serial number was recorded and mapped to the location of installation. This is especially useful for individual parking space monitoring as well as trouble-shooting sensor performance and communication.

The devices were then sealed and covered entirely with epoxy inside secure PVC casing to protect them against moisture and dust ingress (refer to Figure 7).

Figure 7: Sensor preparation

4.5-inch diameter holes were drilled in the ground and the debris was removed. Next, a layer of sand with cement was used to level the bed to ensure a flat surface for devices. The sensors covered in epoxy and PVC casing was then inserted into the hole such that the top of the sensor sat 1/4 to 3/8 of an inch below the surface of the asphalt.

Figure 8: Sensor installation

After installation, a BLE device was used to activate the LoRaWAN™ module incorporated in the smart sensor, which in turn registered the device(s) successfully to the network. Figure 9 illustrates devices successfully communicating packets on the network provider’s platform after registration.

Figure 9: Device communication activity on network

7.5 Data analytics and post-processing

As part of the PoC, we used our own IoT analytics platform to collect the sensor data and provide real-time results and processing of the data. We also developed a mobile application which was given to the parking enforcement officials to inform them in real-time when a driver had parked illegally over the installed sensors. After several months of development for this specific use case, we were able to create an intelligent interface that shows, in real-time, various parameters such as

- Occupied and Vacant Status of individual parking lots
- Illegal car parked status
- Overall Average Occupancy
- Daily and Hourly parking activity
- Historical data – both monthly and weekly
- Popular parking times
- Individual device monitoring
- Individual device status history

In retrospect, through the course of this PoC, the integrated application server / platform has been able to provide the city with information which had never been available prior to this deployment. The city was now able to see, in a transparent fashion, the non-generated revenue which could have been collected from issued tickets ("Challans") for cars which parked illegally in the no parking zones. As an additional benefit, this also helped curb the problem of corruption and lawlessness in the city. Leveraging cloud computing, artificial intelligence, complicated algorithms, and big data processing, the we were able to demonstrate several data sets which helped the city improve the parking management as well as enforcement.

Below, is a snapshot of data collected in real-time during the ongoing PoC and then made available for analysis on SenRa's IoT analytics platform.

Figure 10: IoT Analytics Platform - Dashboard

To ensure the traffic enforcement could be implemented efficiently, SenRa's mobile application was installed on the local law enforcement's android phones to provide them with real-time notifications of the illegal parking at the aforementioned sites. The mobile app gave immediate notifications when a vehicle parked over the sensors and allowed the appropriate authorities to take swift action to clear up the no parking zone to include issuing parking tickets or Challans if required. Refer to Figure 11 for more details on the application user interface.

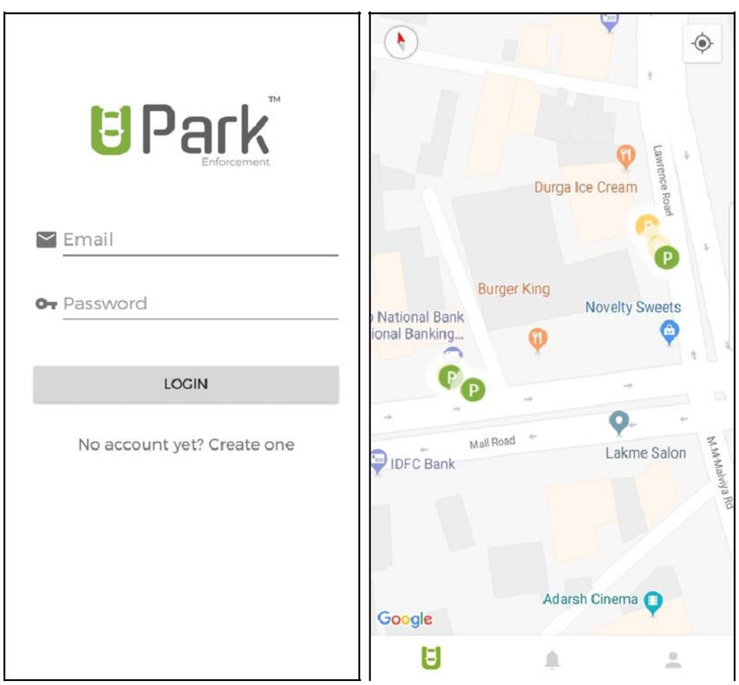

Figure 11: Mobile Application for Enforcement Agency

8 Conclusion

With a rapid rise in number of motorized vehicles in Indian Urban settlements, one can easily see an impending parking space crunch and insatiable parking demands. While the government bodies are becoming more and more aware of this issue, little has been done to incorporate smart solutions that can actually make a difference.

With the ongoing efforts of this PoC, Cities are now realizing that smarter parking solutions can be successfully implemented when leveraging cutting edge technology and in -house expertise from vertical experts. Smart Parking Management solutions would be able to identify and penalize Illegal car parking, introduce variable pricing, ensure unhindered lanes for passage of emergency vehicles as well as enable overall street improvement for all road users.

Through this proof of concept, SenRa has enabled the City authorities to realize revenues never seen before. In addition, it has given a highly competent tool to the enforcement agencies that, if used properly, can completely curb the menace of Illegal Car Parking and reduce traffic congestion in future Smart Cities.