Smart Streets

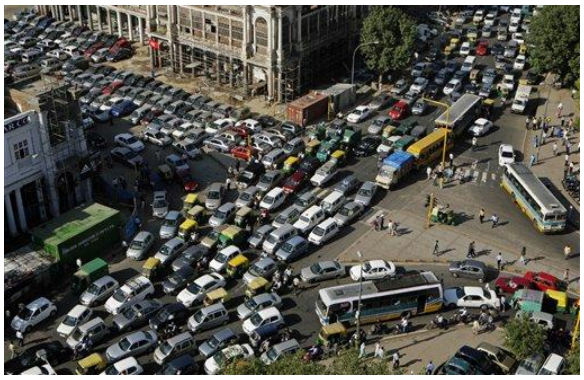
Smart Streets System Design

Smart Streets are a requirement in today's scenario where everything is getting smart. Traffic is such a big problem in today's cities in developing countries that making a cheap and scalable traffic management system is a challenge. Designing a solution which is cheap requires that we do not use cameras for this purpose. This poses problem in product design and architecture considering that magnetic loops are old technology with its own problems of digging the road compulsorily to implement it.

Nascent Info Technologies, with its strong research and development team, has designed an innovative solution derived from a recent doctoral work but different from it significantly, to meet these product design challenges.

This white paper elaborates on the design approach and technology exposure for Smart Streets for traffic management.

Managing this problem:



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Preface

Today, in cities, during late morning and evening hours, the traffic on roads is at peak. This happens due to office going people in late morning hours and people returning from office in evenings. Many Indian cities do not have citizens who abide by the traffic rules every time leading to unexpected congestions and jams here and there. This makes the lives of traffic police men/women difficult.

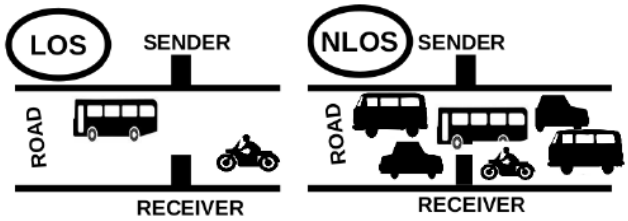
If cameras are installed at all road-junctions, it is a costly solution but charging fine for violating traffic rules for each violator can be too big a task to manage even if the whole process is automated because changing the habits of people is not that easy. Also, it is not feasible to have cameras at smaller junctions because of cost and bandwidth requirements. Instead, providing citizens and police with a way of knowing where the congestion currently is and thus, so that they divert themselves to lesser congested routes, can be a solution. And this white paper will show that it can be done without costly cameras.

The challenge from the application standpoint is to ensure smoother traffic patterns in the city while ensuring better information in hands of citizens and traffic police. While the issue can be approached through the use of cameras, they may not be required and hence a lot of optical fiber cabling costs can also be saved using the technology demonstrated in this white paper.

Concept

The concept of the solution is to have real time data on the status of traffic at junctions. Without using cameras, the idea is to sense the traffic using something that can distinguish between few vehicles and many vehicles on the road. It turns out that there is no cheap solution other than RF waves. RF waves get reflected from conducting bodies like human beings and vehicle bodies. They pass through the non-conducting glass windows of vehicles after some loss. But it is important to use low power RF waves so that the difference due to many vehicle bodies is significant compared to few ones. We use a low power RF protocol at 2.4 GHz as per Indian regulations.

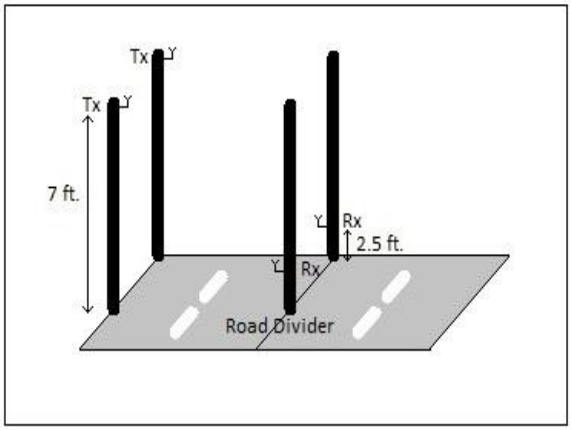
So using sender at one side of road and receiver at the other side is a solution. Line-Of-Sight (LOS) signals get received with better signal characteristics at receiver compared to Non-Line-Of-Sight (NLOS) signals. LOS signals would be received when the traffic is free-flowing and NLOS signals would be received when the traffic is congested.



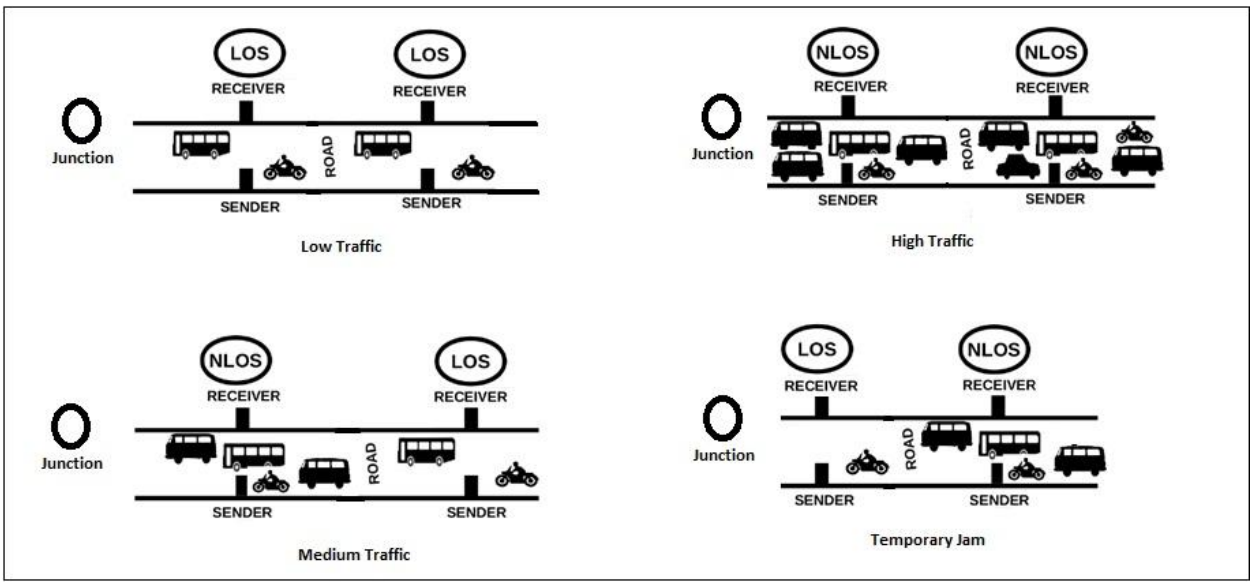
(a) Free-flowing traffic (b) Congested traffic

The Solution

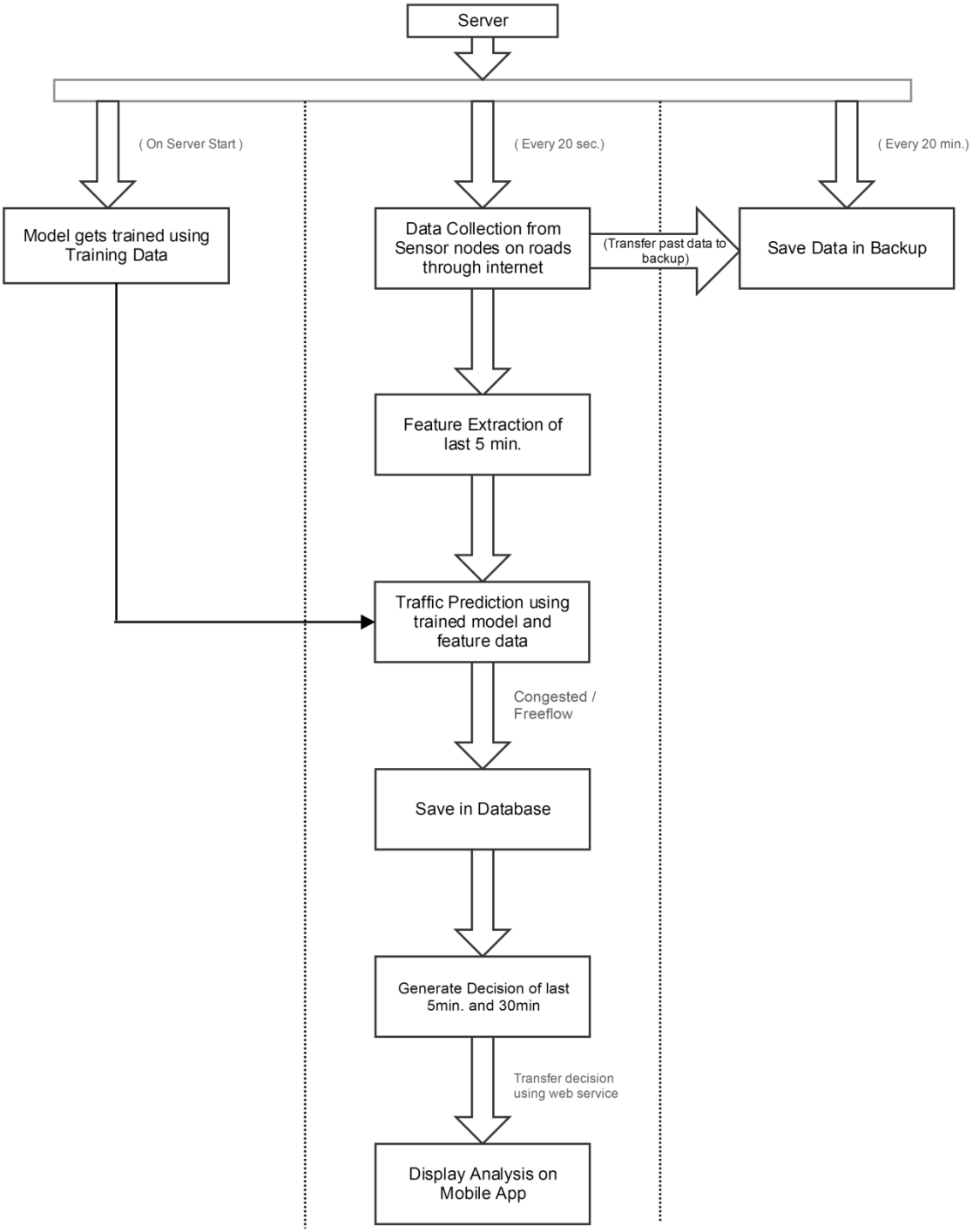
At the left side of road facing towards junction, we place Tx (transmitter) at height of 7 ft. (so that parked cars do not obstruct the signal) and at road-divider, we place Rx (receiver) at height of 2.5 ft. (as shown in the figure). The Tx transmits packets. Rx receives the packets and calculates statistics dependent on the condition of signal received. The radio signal received is not the same as the transmitted signal as it undergoes through reflections from metal bodies of vehicles and passes through glasses of vehicle windows. Depending on the quality of signal received, we estimate whether the traffic in between Tx and Rx is congested or free-flowing. The statistics collected at Rx is sent to server and the server gives the decision of type of traffic based on machine learning for duration of 5 minutes.



If there is LOS (Line-of-Sight) between Tx and Rx, the result will be that the traffic is free-flowing and if there is NLOS (Non Line-of-Sight) between Tx and Rx, the result will be that the traffic is congested. We place two pairs of Tx-Rx on a left-road facing towards a junction. The distance between the two pairs can be fixed based on the type of traffic at the junction, e.g. small distance for a normally free junction and large distance for a normally congested junction. The logic of the decision of the traffic status is that if the traffic is congested at pair near to junction and congested at pair far from junction, then the traffic at that street on junction is high. If the traffic is congested at pair near to junction and free-flowing at pair far from junction, then the traffic at that street on junction is medium. If the traffic is free-flowing at pair near to junction and free-flowing at pair far from junction, then the traffic at that street on junction is low. If the traffic is free-flowing at pair near to junction and congested at pair far from junction, then the traffic at that street on junction is temporary jam. This logic has been depicted in the following figure.


LOS
RECEIVER
LOS
RECEIVER
Junction
ROAD
SENDER
SENDER
Low Traffic
NLOS
RECEIVER
NLOS
RECEIVER
Junction
ROAD
SENDER
SENDER
High Traffic
NLOS
RECEIVER
LOS
RECEIVER
Junction
ROAD
SENDER
SENDER
Medium Traffic
LOS
RECEIVER
NLOS
RECEIVER
Junction
ROAD
SENDER
SENDER
Temporary Jam

System Description



A Machine Learning algorithm is used to derive the results using the above mentioned logic. For the implementation of the Machine Learning algorithm, the system needs training data. So, we collected training data from the possible real scenarios and labeled them as free-flowing or congested. As per the above system diagram, when the server starts, the model gets trained using the training data.

Every 20 seconds, data is collected from “sensors” deployed on roads through an internet connection. Data is backed up every 20 minutes. Of the data collected, features are extracted for last 5 minutes. The status of traffic is predicted as free-flowing or congested using trained data and feature data. The results are stored in database. And then the decision of last 5 minutes is generated. The decision is transferred using web service from server to mobile app. Both Android and iOS apps are created for this.

Design Challenges And How We Addressed Them?

Hardware

- Boards got damaged: A few hardware boards got damaged in our process of learning. We tried to debug the boards and identify the caused problem. Then we made best possible use of the remaining functionality of the damaged boards.
- Fixed destination address so take care while placing nodes: We fixed the destination address i.e. address of receiver node and also kept different channels for different Tx-Rx pairs. So we had to take care while placing nodes with poles.
- Packet losses due to wire antenna: At the beginning we ordered transceivers with wire antenna which was not robust. Many packets used to get lost when bus used to come in between. After learning from our experience, we ordered transceivers with RPSMA antenna, which was costly but effective; its packet losses were minimal and gave signal even when two buses came in between. That happened because the height at one end was 7 ft. and at that height, buses have big glass windows.
- Node design from box to pole: As we did a lot of training and testing, our design for nodes improved from tiffin box on poles to Sintex boxes on poles to poles themselves. Our use of poles also matured from the light Aluminium poles we had, to already existing advertisement or traffic sign poles, to custom made poles of flexible height to 6-inch diameter PVC pole consisting of nodes inside them. This will also be replaced by a strong 6-inch diameter metal pole (in order to sustain strong winds and heavy rains) with a cut where node will be placed which would be covered with PVC there. The cut is required because metal near antenna would affect the signal quality.

Training

- Camera: For training, we required to deploy a Tx-Rx pair and monitor it throughout the day for labeling the traffic as congested or free-flowing. So we had to record the traffic between Tx and Rx using a camera. Initially we used iPhone but ended up in memory problems, so we used multiple iPhones. Then we used digital camera (first, we were avoiding it due to battery problem, and the fact that it cannot be charged until it is off) as we had matured to a level where we required to record for only a few hours, as that much training would suffice.
- Handling the camera: Initially we used to hold the camera in our hand and switch the person holding it from time-to-time. Then while searching for a tripod stand, we came across a flexible stand which could be clipped to any rod or table or any object with similar structure and the camera could be attached to it.
- Fixing node on pole: First we used strong thread to tie the node at the height we want on the pole. Then we used cello tape like thread for the purpose. In our latest design, we screw down the nodes in the poles.
- Long duration: We used to stand for several hours at a stretch during the sunny day to keep an eye even after getting the flexible stand, so that our nodes are not stolen or disturbed by anybody.

- Use of micro-SD card: In our first training we had not connected our nodes to internet, so we had used micro-SD card to store all training data. It involved manual intervention. So, for subsequent trainings we made internet available at nodes and collected data directly at our server.
- Different traffic types: We found that our prediction was not accurate when a very heavily congested road or junction was given to us. So we did three different types of training for different traffic types and we plan to apply different models depending on the type of junction or road.
- Temperature / Humidity sensor: For addressing the challenge of effect of weather on signal characteristics, we included a Temperature and Humidity sensor, one per junction. This would mean different training model for different Temperature / Humidity values.
- Theft or Damage: Our design of thick 6-inch poles came up based on the idea of preventing the theft or damage of nodes. So the poles now have the node inside them.
- Electricity: While in training and testing phases, we used battery for powering the nodes, but for actual 24 hour installation, we would have to provide electric supply as batteries would not last long enough.

Machine Learning

- Decision of parameters: The statistics of the parameters of the received signal would decide the traffic status. The parameters to be used were also fixed upon experimentation.
- Decision of algorithm: The algorithm to be used for classification was decided based on the need to classify the traffic at a Tx-Rx pair as free-flowing or congested i.e. matching the training data of free-flowing and congested traffics to the collected data to find the nearest match.
- Decision of update window: It was upto us to decide the interval at which the traffic status would be updated on the app. And we were displaying the result of last 5 minutes due to accuracy reasons. So we decided to use a sliding window for updates i.e. we update in an interval decided by the load on the server for last 5 minutes. To start with we took the update interval to be 20 seconds i.e. at every 20 seconds we refresh the status in app for last 5 minutes.

App

- Street vs junction vs point: A junction is a cross-roads, while a street is a road with multiple junctions on it. And we invented the term point to mean a place on a road near junction like Prahlad Nagar to Anand Nagar road at Anand Nagar junction. That is, a pair of Tx-Rx pairs would form a point and a combination of points on an intersection of roads would form a junction. And combination of junctions on a road would form a street. We created these terms to show our data on maps on the app in a meaningful form.
- Correct lat-long of pairs and points: While placing the points on the map in the app, the latitudes and longitudes of Tx-Rx pairs and the points were not matching the location on map. The reason was different source of the lat-long. Then we used Google maps to get the lat-long as we were using Google maps for their display, then it got solved.

Potential Benefits

Traffic Police

- The traffic police will be able to organize their police-force as per the real-time traffic conditions. That is, more policemen can be sent to a junction or street with more traffic and less to less traffic areas.
- The above allocation of traffic policemen can be done even in a distributed manner by local traffic police stations or may be even smaller entities.
- The traffic police can do analysis of the traffic data digitally for the whole city or town with such a cheap solution.

Citizens

- The citizens who install the app will be able to get an overall view of the traffic in their cities or towns.
- The citizens will get the traffic status for different routes between same source and destination. Thus they will be able to always take lesser congested routes.
- This will in the long run help distribute the traffic on roads in the city or town.
- Citizens will also be able to view the analysis of the traffic in their cities or towns. This will help them volunteer for the cause of traffic regulation.

About Us

Nascent Info Technologies Pvt Ltd, an Ahmedabad based CMMI Dev Level 3 certified IT / ITeS company which is into software and applications development as well as into Digital Communications.

Nascent Info Technologies specializes in the business of providing services like Software design and development, product planning and development, mobile apps development, data centre management, data centre consultancy and technical support, GIS application development and deployment and Digital Media campaign management. Our expertise helps in reducing costs and enhancing output by bringing the strategic advantage of Software Outsourcing.

Nascent deals with PHP and other Open source technologies, adding Value to information system through R&D. Crafting machine intelligence in line with human intelligence.

Nascent has developed various wide ranges of Mobile apps for smart phone, useful apps for travelers, Book readers, developed comprehensive apps for conducting Survey and integrated apps for ERP as well as decision making mobile based apps for tourism.

We are also dealing in GIS based products and services. Nascent has developed decision making web based tools for hospitality and power sector. Provided services to urban development authorities and municipal corporation authorities and in private sectors too.

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