ICT based Smart Traffic Management System "iSMART" for Smart Cities

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Abstract: ***Improvement in economic conditions and increased standard of living has made it possible for most of the people to own multiple vehicles for personal commute. These increased number of vehicles specifically four-wheeler and heavy vehicles while running on roads causes frequent traffic jams and longer commute time specifically in crowded areas. Unfortunately, putting restrictions on use of vehicles, cannot be the solution for such problems. Instead, a solution pertaining to efficient traffic management can help here. Today's urban cities are prone to face traffic related problems due to increased four-wheeler and two-wheeler uses. To deal with such kind of issues, Smart Cities uses smart traffic management system, which is considered as necessity rather just a requirement. In this paper, a Smart Traffic Management System: iSMART based on IOT Sensors, image processing, GPS and Data Analytics based solution is proposed. iSMART system is not only easy to install and use but also more efficient than many other typical traffic management systems claiming to be smart. It provides route optimization planner based on real time traffic data analysis and considering various traffic situations. The paper has also discussed details of various existing traffic managements systems and their typical features.***

Keywords: GPS, Smart City, Image Processing, IoT, Data Analytics, Smart Traffic Management, V2V.

I. INTRODUCTION

Traffic related issues are day by day increasing to significant extent. During peak hours, in metro cities travelling by road by own vehicles, easily takes around 1-hour time for a distance around 10 to 15 Km. Please refer figure 1 which has shown typical traffic jam situation during peak hours in small to large cities. Considering this, in an average, most office employees who travels by car for commute between office and home, with in 15 km distance, can spend almost 10 to 15 hours' time in a week, in travelling alone. Poor road infrastructure, inefficient traffic management, ineffective traffic rules and shortage of traffic control staff are some of the main reasons for traffic problems. Thus, efficient traffic management system for effective handling of traffic related issues is no longer desire but has become necessity now a days. In Smart Cities around the world, to deal with traffic issues, intelligent Traffic Management System is typically used. Intelligent Traffic Management System analyses the traffic flow in real time fashion and suggests drivers the most optimized route to reach to the destination. It also facilitates recording the traffic footage, informing the latest traffic incidents to relevant stakeholders, providing traffic data for offline analysis, assisting in collecting toll taxes, Signal Controls, displaying signs, warnings and necessary messages at relevant spots across the roads and may other functionalities which can help all the travelers and traffic control staff.

Fig. 1. Traffic Jam during Peak Hours

The Smart Traffic Management System is a complex and comprehensive system to design, build and implement. There are varieties of Smart Traffic Management Systems in place from different organizations. The typical Smart Traffic Management System does not only help in controlling the vehicle traffic but also does variety of other jobs. Apart from traffic control and monitoring the other most important goal of Smart Traffic Management System is to provide safe and secure travel across roads and reduce risk for road stakeholders including drivers, cyclist, pedestrians, operators and vehicle occupants travelling along the roadways.

Fig. 2. Typical Smart Traffic Management System

To ensure meeting this objective, the major activities carried out by Smart Traffic Management System includes following.

- Incident Management
- Road Side Assistance
- Traffic Control and Monitoring
- Emergency Management
- Electronic Toll Collection
- Crash Prevention and Safety

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- Route Optimization and traffic diversion information

From the above listed bullet points it is very well cleared that the modern Smart Traffic Management Systems do variety of jobs including smart and effective traffic control and management. Please refer figure 2 which has shown some of the key infrastructural components of typical Smart Traffic Management System. It should be noted that the IT Infrastructure for Smart Traffic Management System including Servers, Wi-Fi Routers, Ethernet Switch, Internet Cables, Display Screens, LED banners etc. can be part of existing IT infrastructure of the Smart City and can be used on sharable and configurable basis. This can further makes deploying and using Smart Traffic Management System convenient as well as Cost effective in most of the cases. However still it is complex task and requires human intervention and supervision on periodic basis. Let us briefly analyse the major activities carried out by the Smart Traffic Management Systems.

A. Incident Management

It takes care of incident identification, reporting and handling. Typically, the Cameras, Video Surveillance System and Traffic controllers keep watch on traffic movement and activities across roads. If any incident such as accident, fire, theft, natural disasters, traffic blockage, vehicle failure on roads, mob gathering, attacks, etc, happened anywhere across the roads then such incidents are recorded in the system and processed according to set rules and regulations as per traffic laws.

B. Road Side Assistance (RSA)

RSA involves assistance to vehicle drivers in rectifying the problems with the failed vehicles on roads as well as towing such vehicles away from the roads, in case required.

C. Traffic Control and Monitoring

This is one of the main important functions of Smart Traffic Management System where system ensures smooth traffic movement by effective controlling the traffic flows, avoiding of traffic congestion, controlling the traffic diversion and monitoring the traffic movement for needful analysis. Various Sensors, IT components and Control Servers plays an important role in carrying out this important function in collaborative manner.

D. Emergency Management

Any serious incidents which needs immediate attention of authorities falls under Emergency Management category. It can include emergency scenarios across roads such as fire, flood, incidents due to natural disasters, accidents involving heavy to very heavy vehicles etc. In such scenarios the Smart Traffic Management System immediately flashes the Emergency Situation message to all the stakeholders on the available communication medium including cell phones, display screens, LED Banners etc. Note that Emergency Management is very different from Incident Management and it is handled with highest attention and care.

E. Electronic Toll Collection (ETC)

It typically includes automatic toll collection at toll gates without requiring the vehicles to stop. This is typically done via the chip enabled ETC Card which facilitates toll charges debit from ETC Card. The Smart Traffic Management System issues such cards to Vehicle owners/drivers after registering them with the system. It is like prepaid card and the card owner needs to charge the card periodically to maintain enough balance. Note that vehicles which doesn't have ETC card can't use ETC facility and for such vehicles manual toll collection is required.

F. Crash Prevention and Safety

It facilitates detecting the road blockages and unsafe driving conditions and accordingly warns the travellers well ahead of time to avoid crashes. It provides prior alerts for traffic approaching dangerous turns, restricted overpasses, rail crossings, pools, off ramps. work zones etc and thus causes driver to take appropriate action. Many times, these warnings are provided through running sign boards, LED Banners, Displaying Messages over Display Screens and even through static boards. Using Sophisticated electronic systems and sensors made it possible of detecting presence of pedestrians, animals, bicyclists on the road well ahead of time.

G. Route Optimization and traffic diversion information

It includes activities related to alerting the vehicle drivers about traffic diversion in case of traffic diversion situation has arisen. The Alerts can be sent via mobile app, over loud speakers or through displaying messages over LED running board, Display screens etc. Through a dedicated mobile app (similar to Google map) and with assisted GPS and coordination with Traffic monitoring system it is also possible to update the driver over the best optimised route available to reach to the destination at given time.

II. LITERATURE REVIEW

Increased number of commercial vehicles as well as personal vehicles and limited road infrastructure has risen the traffic problems. In developing and developed countries dealing with traffic related issues on daily basis, has become very common. This ever-increasing traffic related concerns has triggered worldwide scientists, engineers and researchers to discover innovative techniques and solutions for effective and efficient traffic management specifically for today's Smart Cities. In this section, some related work is analyzed and reviewed for better understanding of existing solutions and technologies used in developing Smart Traffic Management Systems.

A. B. John F. Gilmore and Khalid J. Elibiary, "AI In Advanced Traffic Management System"

A typical Traffic Management System controls the operation of Signal Indicators according to decided logic. However, in this paper authors have discussed the use of Artificial Intelligence in Traffic Management System covering the operations of the overall transportation system of surface streets, interstate highways, public transportation, and emergency vehicle response etc. Authors have claimed that Artificial Intelligence based Knowledge sources in the system addresses problems in traffic congestion, incident management, traffic control and monitoring. Authors feel that Artificial Intelligence based knowledge gathering exploit neural network representations, rules, script frames to solve individual traffic management problems.

Authors have also successfully proved that the resulting traffic management decisions based on Artificial Intelligence are implemented and evaluated through simulations.

B. C. Robert L. Bertini and Ahmed El-Geneidy, "Advanced Traffic Management System Data"

In this chapter, authors have presented a holistic view about Intelligent Traffic Management System and successfully clarified that the intelligent traffic management system in a whole consist of various subsystem components such as Incident management, Transit Management, Electronic Payment, Traveler Information, road infrastructure operations and maintenance, freeway management, emergency management, crash prevention and safety and road weather management. Authors have argued that for smooth functioning of intelligent management system, all these components should be in place and each subsystem cannot be deployed in standalone fashion while dealing with overall transportation system. Authors have also clarified that building a complete intelligent traffic management system requires time, money, institutional arrangements and lot of collaboration among stakeholders. All the integrated subsystem components then can result in synergistic effects. simulations.

C. D. Hasan Omar Al-Sakran, "Intelligent Traffic Information System Based on Integration of Internet of Things and Agent Technology"

In this paper, author has presented traffic management and administration system based on IoT. Author has claimed that such system is better compare to the traditional traffic management system in terms of cost, upgradation, scalability and compatibility. The proposed Traffic management system makes use of Internet, an active radio-frequency identification (RFID), object ad-hoc networking, wireless sensing and detection technologies to realize the intelligent recognition on the tagged traffic object, monitoring, tracking, managing and process automatically. Author has proposed the system architecture that integrates IoT with agent technology in single platform where the agent technology handles interfacing and communication among large number of heterogeneous, highly distributed and decentralized devices within the IoT. simulations.

D. Andreas Allstrom et al, "Traffic Management for Smart Cities"

Here authors suggested that traffic related large data is already available from various Sensors installed for road traffic observation. If this data is properly organized and processed it can provide various useful information to the road users such as travel time, real time traffic states, travel pattern dynamics and so on. Authors have claimed that by using proper data filtering, algorithms and modelling techniques the meaningful information for road users can be extracted and such data can also be used for wide area traffic control. Authors have also pointed out using the data for analysis which is shared among vehicles over V2V link within cooperative systems. Such data analytics can help us deciding better traffic control strategies.

E. Jiandong Cao, "Research on Urban Intelligent Traffic Monitoring System Based on Video Image Processing"

In this paper, Author has proposed Video and Image processing technology for intelligent traffic monitoring system. The paper has described in detail the functional design of Smart Traffic Monitoring System with video image processing and database analysis. In this paper author has claimed that proposed video and image processing solution can provide intelligent analysis to the traditional traffic control system with the association of relevant data analytics. This can save lot of manual monitoring and control processing besides real time analysis can also offer very high efficiency. The proposed solution by Author, processes the image data of Vehicle License Plate with the help of high definition camera. The Author has proposed solution using the object recognition algorithm based on Haar features combined with AdaBoost classifier. Author feels that Training the classifier for vehicle detection by a large number of images at the car tail can achieve the rapid and effective identification of the front vehicle in the high-grade highway environment. The relevant image processing also considers the data analysis with respect to Vehicle speed, Vehicle body color etc. The combined results are stored and analyzed.

III. PROPOSED SMART TRAFFIC MANAGEMENT SYSTEM: ISMART

The proposed Smart Traffic Management System, "iSMART" is based on IoT based sensors, secured communication, GPS and Client Server Technologies. This system is prototyped to showcase how effectively existing IT infrastructure of Smart City can be leveraged to design, build, operate and maintain a cost effective but powerful Intelligent Traffic Management System. Let us explore the architecture and major building blocks of iSMART.

The major components of iSMART are as follows

- Smart Traffic Management Server: This is a central server available at city level and responsible for overall city traffic control and administration. It receives data over wired or wireless connections from various Node Controllers and Signal Controller Units connected over high speed secured ethernet communication channels. This Server also communicates with Central Database which is responsible for secure storage of traffic relevant data with time stamp.
- Central Traffic Database: A reliable and secure database which is used to store and retrieve the traffic incidents data, traffic images, traffic videos, traffic analytics data and period wise traffic reports. Central Traffic Database is built up with MySQL database and it receives the storage data from Central Server. Central Traffic Database also provides relevant data back to Central Server as and when queried and demanded by it.

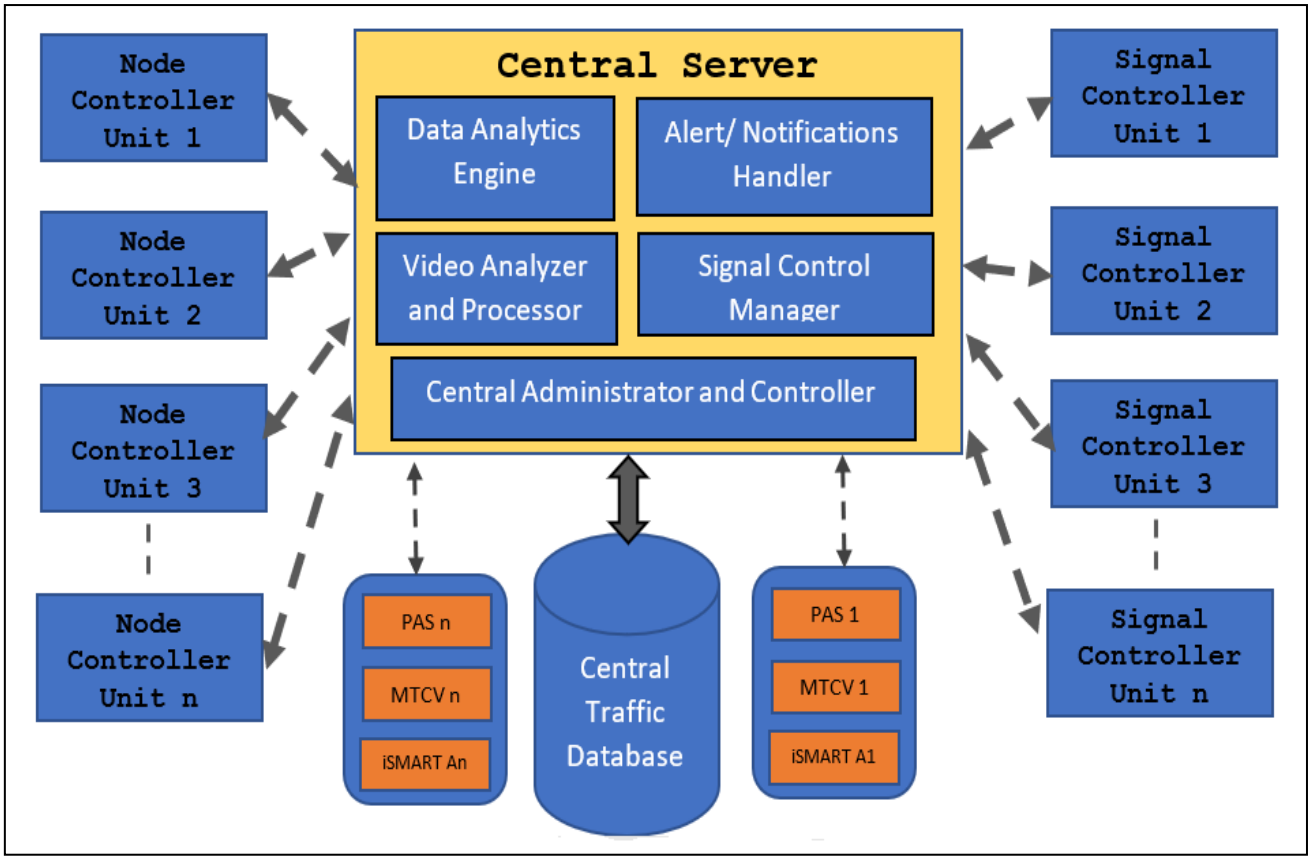

Fig. 3. High Level Block Diagram of iSMART System

Node Controller Unit: Node Controller Unit (NCU) represents various areas distributed across city road infrastructure. Typically, each Node Controller Unit needs to be installed at every 500 meters distance across city roads depending upon typical traffic prone areas and at roads going through population dense areas. Each Node Controller Unit consists of a 32-Bit Embedded Controller operating with Node Control Application Software, Image and Video Streaming Algorithms and alarms and notifications handlers. The purpose of Node Controller is to monitor the city traffic, record the emergency and traffic jam relevant incidents. Node Controller gets data over secured communication channel through various Image Sensors, iSMART Mobile App, (To be operated by personnel such as Traffic Police, Authorized Volunteers for Traffic Control, Traffic Admin Staff etc.) and from Signal Controllers. Node Controller regularly analyses the traffic images and videos and keeps track of emergency situations reported through iSMART Mobile App. It also receives updates from Signal Controller such as Signal Control malfunction, Signal Control time outs etc. Node controller runs with data collaboration and analytics Application Software and send the crisp report of real time traffic data, relevant traffic footages to central server over secured ethernet channel at regular interval of time. Each Node Controller Unit receives the real time traffic images and videos from IOT based image sensors which include day and night vision Cameras, Thermal Cameras and high resolution PTZ Cameras. NCU also receives images, videos and location data from MTCV (Mobile Traffic Control Van) and there can be at least 4 to maximum 24 IOT based image sensor Cameras installed in distributed fashion in various areas to which Node Controller is responsible to monitor and control the traffic. Each NCU is responsible for traffic monitoring of around 200 to 500 meters of roads at each up and down side. The Cameras are typically mounted on 10 to 20 feet high pole and or Signal Poles as per the requirement and demand via NCU.

- Signal Controller Unit: Signal Controller Unit (SCU) as the name suggests is a controller unit for traffic signal control for the applicable Node. The SCU and NCU always works in synchronization with each other and SCU keeps the information of latest signal events updated with NCU at regular interval. SCU's main responsibility is to control the traffic Signal indicators (Red, Yellow and Green) according to real time traffic algorithm outcome. The time control values are regularly suggested by NCU to SCU for further necessary actions. The SCU is implemented using the 32-Bit Embedded Controller operating with Free RTOS. SCU also ensures informing the signal feedback to NCU in case of any failure or malfunction. There are multiple SCUs for one node and each SCU communicates with NCU over secure ethernet. NCU acts as a Server where as SCU acts as a Client. Note that SCU drives the Signal indicators through relays and the signal indicators are typically LED Lights.

Other elements within the iSMART system are

- Control Relays
- LED Lights
- Power Supplies
- GPS
- Ethernet, Signal and Power Supply Cables
- Switches
- MTCV
- Public Address System (PAS) and
- existing IT infrastructure

Here the existing network IT infrastructure is basically for interconnecting various network elements through wired or wireless secured ethernet communication and the display television sets installed across roads are used to update the traffic information regularly to travellers. Note that relays are drive through GPIO Lines by Signal Controller Units. The signal indicators are LED Lights which are powered through constant current driver and are mounted typically on mounting poles as well as a series of string through a small metallic enclosure across zebra crossing lines over roads. Power Supplies are typically AC to regulated DC Converters operates over mains AC supply and generates regulated DC Power of 24V DC to power the electronic equipment including embedded control units, LED Signal Indicators, Relays, indicator Switches etc. Note that the manually operated switches are used to control On and Off of Embedded Control Units as well as manually control the Signal Indicators. The Signal indicators can be manually controlled by Traffic Police and authorized traffic control volunteers. Manual Operation for Signal Indicators shall always override the decision from electronic control circuitry. GPS are Global Positioning System which are mounted in MTCV along with GSM Modem to provide location coordinates of MTCV. The data from MTC is fed in to the respective NCU which belongs to that particular node where MTCV is operating. MTCV plays a big role of manually controlling the traffic specifically at isolated and at remote places where regular traffic control staff is not present.

IV. MAJOR FUNCTIONS AND FEATURES OF ISMART

While developing prototype of iSMART, the best possible features and functionalities of Smart Traffic Management System were considered keeping in mind the aspects such as simple design, easy operation, effective use and low deployment/operation/maintenance cost. The Proof of Concept (POC) developed for iSMART is tested locally in a laboratory environment using simulated high-volume traffic data, traffic related reference images and videos, GPS reference location coordinates and simulated incidents scenarios/messages. Let us walk through major features and functionalities supported by iSMART.

A. Traffic Control and Monitoring

Here NCU and SCU works in collaboration with each other and based on control strategy decided by Central Server, control and operates the traffic Signals. Unlike traditional traffic control algorithm used by typical traffic controllers, iSMART controls and monitor traffic based on real time video and images supplied by IoT vision sensors for real time traffic scenarios, data provided by MCTV and iSMART Mobile App.

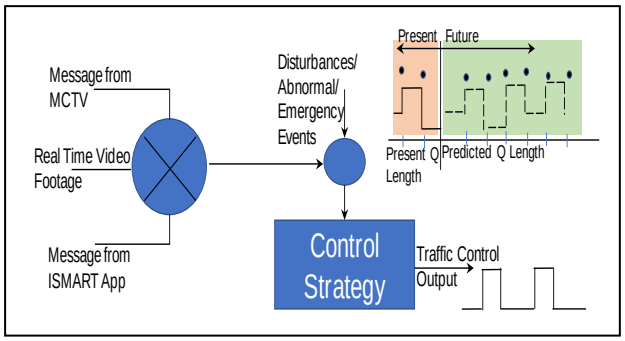

Fig. 4. Basic Building Blocks -Traffic Control Strategy

Base on the information received from various sources and the processing of traffic video footage, NCU classifies the traffic scenarios in 6 different categories as follows.

- Traffic Jam
- Traffic Very High
- Traffic High
- Traffic Moderate
- Traffic Low
- No Traffic

Table I: Traffic Control Cases

Sr. No.	Traffic Scenario	Action	Remarks
1	Traffic Jam	Manual, Semi-Automatic	Manual Control, Need for Traffic Diversion
2	Very Heavy Traffic	Auto Control	Some manual Control may need
3	Heavy Traffic	Auto Control	No Intervention
4	Traffic Moderate	Auto Control	No Intervention
5	Traffic Low	Auto Control	No Intervention
6	No Traffic	Auto Control	No Intervention

Please refer figure 4 which has shown the input sources and control algorithm output for the present and predicted future traffic state. It should be noted that the emergency such as movement of convoy, Ambulance running in wrong direction, sudden vehicle failure on road, can lead to disturbances and abnormal traffic scenarios, and such inputs are also taken into account while deciding the traffic control strategy and traffic diversion related decisions. The control algorithm software runs on NCU whereas actual controlling of signal lights is done by SCU. The control algorithm output decides the duration of GREEN and RED light indication. The ON Period in output signal is applicable for GREEN Light whereas OFF period is applicable for RED Light.

The Yellow light duration is standard and can be preconfigured as per the six different traffic scenarios as listed in Table 1 above. It should be noted that SCU facilitates manual mode of operation where traffic controller and authorized staff can manually operate the Signal Indicators by turning ON or OFF the specific Signal Indicator lights as per situation demands. Such manual operation overrides the automatic control logic and, in such scenarios, the SCU remains operational in manual mode unless not switch back to Auto mode by the operator. Kindly note that the control strategy decided by Node Controller is applicable to the respective SCU only and it can differ from one SCU to other as per the situations demands.

B. Incident Management and Emergency Management

iSMART POC doesn't have separate Incident Manager Server rather Incident Management including Emergency Management is carried out by iSMART Central Traffic Management Server in collaboration with NCUs. Here the incident detection is carried out by IoT Vision Sensors, MCTV and Traffic Control Staff in collaboration. The specialized video processing software as a part of NCU Application Software tries to identify any incidents happening initially. The incident location is subsequent confirmed by MCTV and or Traffic Control Staff by pressing relevant alert controls over iSMART Mobile App. The Alerts are then sent to iSMART central Server by NCUs through a network message specifying the location coordinates, real time footage of the scenarios and the incident category. The iSMART Central Server on receiving the Incident message, updates the database with incident information and alerts the Ambulance Service/Fire Brigade/Emergency Rescue Team/ National Disaster Recovery Force etc. as the case may be by sending the Email/SMS Notification and recorded audio call on the given help line number. The typical contents of Incident message are as follows.

Table II: Typical Message Format

A	B	C	D	E	F	G	H
1 B	1 B	1 B	8 B	8 B	1 MB	1 B	256 B

Where the first Row represents the reserved Data Fields as specified below and the second row represents the reserved data size for each field.

A: Message ID

B: Incident Category

C: Incident ID

D: Location Coordinates

E: Time Stamp

F: Incident Video Stream Compact Data

G: Priority

H: Text String for Remarks

Note that the network message always ends with EOM (End Of Message) field represented with unique data to ensure identifying and parsing of various data messages easily. There is also a facility of encrypting all the messages with selected encryption algorithm. The present POC was however tested with non-encrypted message communication for keeping the design and operation simple.

Various Incidents Category supported are as follows.

Table III: Incident Categories

Sr. No.	Incident	Category	Actions
1	Vehicle Failure on Road	Minor	Communication to RSA Team
2	Traffic Jam	Minor	Communication to Traffic Controllers
3	Riot/ Mob Gathering	Major	Communication to Police
4	Accident Minor	Minor	Communication to Medical Team
5	Accident Major	Major	Communication to Medical Team and Ambulance Service
6	Fire	Emergency	Communication to National Disaster Recovery Team/ Homeguard/Military
7	Earthquake	Emergency	
8	Flood	Emergency	
9	Terrorist Attack	Emergency	Communication to Military and Police
10	On road disputes	Minor	Communication to Traffic Police

C. Electronic Toll Collection

In India NPCI has developed the NETC (National Electronic Toll Collection) program which facilitates automatic toll collection through moving vehicle which is attached with a RFID Tag known as FASTag. FASTag enables a customer to make the toll payments directly from the account which is linked to FASTag. The FASTag based Electronic Toll Collection allows toll payment without stopping the vehicle at Toll Gate. It is an independent system and doesn't have any direct link with iSMART system.

Still today not every Toll Gate in India has been enabled with Toll payment through FASTag based system. Meanwhile, to further simplify the operation iSMART has proposed much simpler process. The iSMART Mobile App can facilitate the payment of toll charges for the specified Toll Gate over selected route electronically. For this purpose, it is necessary to integrate the iSMART App with the payment Gateway. The payment Gateway can facilitate online payment transaction depositing the collected toll charges with in the NETC enabled account. The successful payment will generate an online receipt with the payment transaction number. This number will be required to make available with Toll Gate Server for verification and record. Once the Vehicle approaches to the Toll Gate, the payment transaction number can be verified at Toll Gate.

The Transaction number verification may need Vehicle to stop at Toll Gate for verification purpose however in near future even communication of payment transaction number through available communication medium such as Wi-Fi, Bluetooth can make possible of having the entire communication while the vehicle is moving.

Fig. 5. My FASTag App UI Screen (Source NHAI)

Refer figure 5 above which has shown user interface for My FASTag App from NHAI (National Highway Authority of India). This Smart App is Bank Neutral App where user can link it with the personal bank account number for toll payment transaction purpose.

A. Route Optimization/ Traffic Diversion

iSMART facilitates Route Optimization feature through iSMART Mobile App with assisted GPS and map data provided through Google Maps App. The App facilitates user to provide start location and destination and based on real time traffic data, navigation information, traffic conditions it recommends the user (vehicle driver) the best optimized route to reach to the destination from the specified start location Refer figure 6 which has shown the Route Optimization Planner.

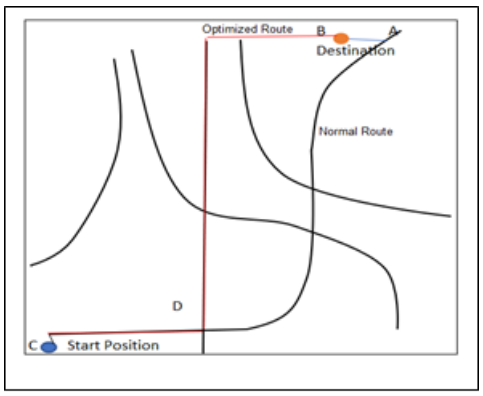

Fig. 6. Route Optimization Planner

Various elements in Route Optimization Planner are described in Table IV as follows.

Table IV: Route Optimization Planner Elements

Sr. No.	Items	Remarks
1	Blue Circle	Start Position
2	Red Circle	Destination
3	C-D-A-B Path	Normal Route for travel between Start point and destination
4	C-D-B Path	Optimized path – indicated by RED line

Note that the iSMART route optimization algorithm consider following conditions while recommending the optimized path. Vehicle relevant fields user need to enter into the app before starting the journey whereas other fields data iSMART App either calculates or fetches from Google Maps App.

- Route Availability: If not a highway, at least a four-wheeler road should be available to reach to destination
- Permissible Road Intersections
- Vehicle Type: Commercial Vehicle, Personal Vehicle, Passenger Vehicle
- Vehicle Category: Two-Wheeler/ Three-Wheeler/ Four-Wheeler/ Heavy Vehicles with 4+ wheels
- Vehicle Load: For Commercial vehicles
- Current Traffic Condition: Traffic Jam/Very Heavy Traffic/ Heavy Traffic/ Moderate Traffic/ Low Traffic/No Traffic
- Traffic Situation: Emergency/Incidental/Normal
- Time required to reach to destination: Based on traffic situation and condition, vehicle category

Kindly note that route optimization feature is applicable for individual journeys performed by the users at their own convenience and it is facilitated through iSMART Mobile App which is still in prototype stage and available for Android Smart Mobile only as of now.

Traffic diversion feature is available at iSMART system level and comes into effect based on manual enabling from Traffic Control staff for the applicable route. Traffic diversion becomes necessity under any specific incident such as accident, fire, natural disasters, VIP movements, political rallies, mob gathering etc. In such events the iSMART central Server updates the traffic database and record and communicates with respective NCU about change in traffic routes. The NCUs of affected route then communicates with respective SCUs and keeps the RED signal Indication ON with traffic Diversion Arrow or “Traffic Diverted” message displayed on digital banner, digital display etc. indicating Traffic Diversion is active. Traffic Control Staff as well gets notifications and alerts over iSMART App as well as their registered Mobiles through SMS and respective staff then also puts the barricades and or Traffic Diversion boards at respective routes to indicate Traffic Diversion.

Please refer figure 7 which has shown various ways to indicate traffic diversion is active.

Fig. 7. Traffic Diversion Signs and Displays

V. RESULT AND DISCUSSION

The iSMART Proof of Concept (POC) is designed keeping in mind some of the most essential features of Smart Traffic Management Systems used for Traffic Control and Management in Smart Cities. The iSMART POC is tested in laboratory environment with simulated traffic data, traffic video footage captured of real traffic scenarios and the map data obtained through apps like Google Map. COTS Items including the Vision Sensors, Freeware Software and development tools and High-end desktop machine operating with Windows are mostly used to implement the POC. The initial test results are found very encouraging. The iSMART Mobile App is developed to operate with Android Mobile Phones only. This App is a handy tool for drivers and passengers for an easy interface with iSMART System. Though many of the features are tested with simulated data, there is a good scope of further improvement with iSMART given the fact that many of the features and functionalities are still remained to be implemented in the system.

The POC was discussed and concept was demonstrated in front of some users for quick feedback. Users appreciated the concept considering the short time for overall development and use of free license Software tools and low-cost hardware items to build up the overall solution. Users also made some useful suggestions for further improvement. Some of the suggestions made are as follows.

- Updates of real time traffic using V2V Network: Use of Public Address System may not be an effective communication mechanism for large and distributed group of stakeholders (Drivers, traffic Controllers, Vehicle Passengers, operation and maintenance staff etc.) Vehicle to Vehicle communication channel over dedicated frequency band should be used to update the vehicle drivers and passengers to update on the various traffic scenarios and situations like possible traffic jams, road closed, traffic diversion etc.
- Route Optimization: Apart from recommendations on best optimized route based on real time traffic data, it is also good to provide the additional information considering past historical data such as
  - ✓ Typical Traffic Scenarios for the specified journey date and time, in past
  - ✓ Possibility of traffic jams
  - ✓ Typical time to reach to destination with specified vehicle type and load carrying by the vehicle
  - ✓ Toll gates on the specified route and possible toll charges to be paid
  - ✓ Nearby available parking lots for the destination
- iSMART App should be made available with other mobile operating systems as well specifically for IOS Phone.
- The iSMART system should also provide access to some kind of dashboard system where the real time traffic updates and historical data trends (seasonal traffic data, weekly data updates etc.) are available and can be visible to authenticated users for better planning of their long journey trips in advance.
- Apart from Vehicle passengers, drivers, traffic controllers and other stakeholders, traffic alerts and notifications should also be made available to smart city residents of the respective affected areas over mobile phone for situation alerts and better preparations in case required. If this facility can be provided to registered users (Smart City citizens) it can have a larger positive impact in the better interest of larger stakeholders of Smart City.

VI. CONCLUSION

The purpose behind iSMART system was to demonstrate the concept of intelligent and or Smart Traffic Management System for today's Smart Cities. The Smart Traffic Management System has become a necessity now a days for effective control and better administration of city-wide traffic and its associated operations. iSMART POC has successfully proved and demonstrated that how a low cost, Smart Traffic Management System can be designed and built by using available IT Infrastructure, Off the Shelf Embedded Hardware Boards, Sensors and Free license Software. Though the POC has not full-fledged implemented all the features and functionalities of Smart Traffic management System, it is undoubtedly proved the usefulness of Smart Traffic Management System and some of its essential features. It has also provided insights on how we can implement and use various useful features of today's Smart Traffic Management System.

It should be noted that today's Smart Traffic Management System's role is not limited to only traffic control and monitoring but it goes well beyond it. Latest technologies such as IoT, Machine to Machine communications, Advanced Video and Image processing, Secure Data Communication and Transmission, Advanced Data Analytics have made it possible to have recommendations of best routes well ahead of start of journey, paying of toll charges with vehicle moving, traffic situation alerts and notifications at right time, collaboration among vehicle drivers/passengers through V2V Communication, better incident management, effective handling of emergency situations on roads etc.

The limited verification and validation results for iSMART POC are found very interesting and encouraging. To get the full benefit of using Smart Traffic Management System with in real Smart City infrastructure, it is recommended to develop the full-fledged iSMART system as per iSMART specifications.

VII. FUTURE WORK

The POC of iSMART: Smart Traffic Management System has undoubtedly proved the usefulness of having Smart Traffic Management System in place. To have the full benefits being offered by iSMART system, it is recommended to implement the overall iSMART System as per iSMART specifications, in future. It is also proposed to undertake following value-added improvements in present iSMART System

- Route Optimizer with additional information such as nearby Parking lots, possible time to reach to destination and estimation on Toll charges
- Apart from Android, iSMART APP for IOS Mobiles.
- Toll charges payment through iSMART APP
- Access to Traffic Dashboard via Central Traffic Server for authenticated users i.e. Smart City Residents
- Traffic Alerts and Notifications for Wider stakeholders including Smart City Citizens for the respective traffic areas. Such Alerts and notifications can be enabled or disabled by the Smart City Citizens based on the applicable settings.

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