Wireless Multimedia Sensor Networks for Road Traffic Surveillance and Management

G. Vithya and B. Vinayagasundaram

Abstract

Sudden and precarious changes in vehicular traffic are most commonly found in large cities. GPS receivers are currently used to balance such changes. But GPS receivers do not always serve to be the best solution, since their reception ranges are minuscule and also because they cannot work in indoor, in tunnels or in dense urban areas where there is no direct visibility to satellites. Sensors deployed on the road side Unit (RSU) and in the on Board Unit (OBU) come handy in solving such paramount conundrums, thus making traffic management less onerous. This paper deals with (i) congestion free data transfer (ii) low processing overhead (iii) flexible prioritization of traffic. In this paper; we investigate these challenges and proposed a scheme for effective and efficient vehicle-sensor and sensor-sensor interactions to support QOS Routing, aided by Context Consistency Aware Routing for Smart cities (CCAR). The algorithm shows that the working of a Sensor in MANET is much better than GPS used for smaller areas in VANET. CCAR routing is carried out by Event processing, Message processing, Context consistency, and consequently (i) Delay are minimized (ii) Priority is assigned for packets and transmissions depending upon its type (iii) Context consistency is validated with time.

Introduction

The major idea of smart city routing is to connect smart environments/spaces and self-aware identities. For instance, smart transport, cities, buildings, rural areas, living conditions etc. can be considered as smart environments. In the road traffic surveillance, every speck in the city is linked to communicate with each other. The traffic is burgeoning at a perilous rate due to increase in vehicles, increase in the number of Internet-enabled services and rapid growth of Internet connected edge-devices. Hence, traffic management is mandatory. VANET provides modern applications like Advanced Traveler Information Systems (ATIS), Route Guidance Systems (RGS), Advanced Traffic Management Systems (ATMS), Performance Monitoring and Congestion Management. In VANET, GPS alone cannot consummate the entire management process.

In VANET a Vehicle can join and leave the Network much more frequently. This indicates the topology in VANETs changes more often. Providing Location-specific traffic information and warnings serves as a solution for advanced traffic management system, also increases road safety. An advance traffic management system supports variable speed limits, adaptable traffic lights, automated traffic intersection control, accommodating ambulances, fire trucks, and police cars. By deploying sensor with 802.11p (WAVE) standard in traffic management, traffic flow is eased.

Sensor nodes, MANET and Mesh networks are used for surveillance purposes, monitoring the safety, Traffic, Business and weather condition to make the city a Smart city. Sensor nodes are deployed along the roadside to sense road conditions, and to buffer and deliver information about dangerous conditions to vehicles regardless of the density or connectivity, the images also to be sent to concerned department to take action.

This paper is organized as Related Work in session 2, proposed work in Session3, Comparative study in Session 4 and Conclusion in session 5.

II. Related Work:

The key challenge faced by VANET is providing communication links between vehicles, travelling at a very high speed away from each other. When two vehicles move in the opposite or same directions, passing each other at a high speed, (usually Car speeds of 60-90 km/h) the amount of time they are in each other’s wireless
transmission range can be a few seconds or less. Therefore if a message has to be passed from one to another, it should be done very quickly. In traditional VANET, the connection establishment takes a considerable time by the factors such as troposphere distance, signal interference on busy traffic, tunnels and thick forest road and also the failure of hardware might lead to conundrums in the data transfer. Also, when using GPS, temporary data might not report the exact location of the satellite because of obstacles such as buildings, trains, electronic obstacles, crowded trees and so on.

Baraa T. Sharef (2010) finds the unique challenges as, highly dynamic topology, frequently disconnected network, hard delay constraints, high application requirements on data delivery. VANET can be disconnected due to high mobility and unpredictable movements of vehicles and the sparse deployment of roadside stations. If the VANET is disconnected, critical information about road conditions known by one part of the VANET cannot be shared timely with vehicles that need to know it but are in other partitions.

Hua Qin and Zi Li(2010) achieve the goal of improved road safety and significantly reduce the number of road fatalities. GPS alone will not be able to fully achieve this goal. To manage Advanced Traffic Management Systems (ATMS) an additional infrastructure called Wireless Sensor Network (WSN) is required. VANET can also use Wireless Sensors as the base for localization, Movement, Climatic condition and for traffic management.

K.B Priya Iyer (2013) maintains a location based service for security. Attackers easily find the location from anywhere. This is solved by deploying more 802.11p Multimedia sensors on both sides of the highway roads called roadside Unit (RSU) to maintain the gated Network and by the sensor nodes in vehicles called onboard Unit(OBU). Mohammad Jalil Piran and G.Ramma Murthy(2010) stated that vehicular nodes have the ability to collect data and route data to the base stations. Sensor readings are routed to the end users by multi-hop infrastructure architecture via intermediate nodes i.e. RSU nodes.

K.Prasanth (2010) reported that conventional routing protocols in MANETs (Mobile Ad hoc Networks) are unable to fully address the unique characteristics in vehicular networks. Laila Esme(2011), analyses the performance and proved that 802.11p is suitable for VANET.

The message priorities which are assigned based on message urgency, are associated with different quality of service in terms of average delay and normalized throughput (Udit Agarwal, Monika Saxena (2013),vithya (2014). By using Wireless Multimedia Sensor Networks(vithya (2011) (i) Delay is minimized (ii) Priority is assigned for packets and their transmissions based on type. N.Celandroni (2013) reported that satellite-based wireless sensor can be used in traffic surveillance.

**MATERIALS AND METHODS**

Normally, a traffic system is managed cogently by applying variable speed limits to increase or decrease the speed of the vehicle. An Intelligent traffic light signal is for regulating traffic by giving preference to the density of traffic rather than monotonous time based traffic. An automated traffic intersection control is provided for accommodating ambulances, fire trucks.

It is particularly challenging to develop a “One-Queue-fits-all” solution by following the classical approach. The proposed algorithm known as Context Consistency Aware Routing is expected to provide a solution to many of the major challenges. The traffic Surveillance with Multimedia Sensor (WMSN) is in the Fig1.

![Fig 1: WMSN Surveillance System.](image-url)

**3.1 Topology of the surveillance:**

Adaptable traffic lights and automated traffic intersection control for the surveillance with the Wireless Multimedia Sensor Network is carried out by the following (i) Vehicle to Vehicle (Adhoc Network),(ii) Vehicle
to RSU (WLAN Network-802.11), (iii) RSU to RSU (MANET-802.11p) in order to provide variable speed limits.

3.1.1 Vehicle to Vehicle: (OBU to OBU):
In cluster-based routing protocols, the vehicles close to each other form a cluster. Every cluster has one cluster head which is responsible for intra- and inter-cluster management purposes. The intra-cluster nodes interact with one another through direct links, whereas inter-cluster interaction is performed through the cluster heads. In the CBDRP protocol [8], the vehicles which travel in the same route are split into several clusters. Each vehicle can communicate via radio with its neighbor clusters. If the OBU in the car comes across any of the scenario like crossing of animal, fire, traffic, road condition, mechanical problem in car, accident etc., then the Cluster Head node broadcasts a data message containing the ID of the above events. When the message reaches OBU, the Car Area Network (CAN) converts the image as to Image ID. If the RSU is in transmission range of Cluster head node (OBU), then the same message is reached to RSU also.

3.1.2 Vehicle to RSU: (OBU to RSU):
RSUs are deployed at a fixed distance along both the sides of the road. The OBU sends the beacon signal to RSU, which contain the ID of the Vehicle. On receiving the data from OBU, it retransmits either towards next RSU or to OBU depending upon the priority of the message. These nodes are equipped with two kinds of antenna, unidirectional and bidirectional. Unidirectional antenna is for broadcasting and bidirectional antenna is intended for Transmission. OBU senses the image and transfers the information in the packet format shown below, in Table1.

<table>
<thead>
<tr>
<th>Event Time</th>
<th>OBU ID</th>
<th>Event Data</th>
<th>Event ID</th>
</tr>
</thead>
</table>

Table1: Packet format of OBU

<table>
<thead>
<tr>
<th>Format of OBU:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Features of RSU: 1. Traffic Analysis: Traffic is estimated by the number of vehicles in the street, also considering the length of the street in meters. Traffic analysis is done by taking into account, the number of OBU beacons between the RSUs at the start and end of the street. 2. If the link between two vehicles is broken or if they are not in the transmission range, then RSU comes into play and helps to relay packets to the destination vehicle. 3. Accident Detection and Reporting System (ADRS) which can be placed in any vehicle makes use of sensors to detect the accident. The microcontroller takes decisions on the traffic accident based on the input from the sensors. The RF transmitter module which is interfaced with the microcontroller will transmit the accident information to the nearby RSU. 4. When the vehicle’s speed is more than the authorized velocity, a report will be sent to the RSU nodes. The fine will be collected from the Car.</td>
</tr>
</tbody>
</table>

3.1.3 RSU to RSU:
RSU is a particularly challenging task due to the fact that OBU is dynamic and significant events alone are routed to the other end of the road or destination. Significant events are prioritised by the intelligence bestowed on the RSU. So RSU needs to act as a sense, relay and sink Node in order to avoid packet drops during surveillance.

Routing Between the RSUs:
In a city, if a vehicle encounters a critical situation such as congestion, fog, ice or an accident. It can pass the relevant information to all road users in the immediate vicinity of the danger spot. Traffic approaching from further away is given ample warning and can respond to the situation.

While travelling through by-pass roads or long roads where the populace is less, people may not be available for immediate rescue, if an accident occurs. Recovery actions should be taken in time to reduce the loss of life and property. Priority of packet transmission is required to reach the information to service providers such as Hospitals. The entire problem is broken down into phases and solved with the an algorithm named as Context Consistency Aware Routing (CCAR) that solely aids the Road Side Unit (RSU).

CCAR consist of three phases namely, Event processing, Message processing, Context consistency checking.
The following are some important scenarios taken as examples as shown in fig2.

<table>
<thead>
<tr>
<th>Event Time</th>
<th>OBU ID</th>
<th>Event Data</th>
<th>Event ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.30</td>
<td>51AC</td>
<td></td>
<td>Ev1</td>
</tr>
<tr>
<td>10.10</td>
<td>43CX</td>
<td></td>
<td>EV2</td>
</tr>
<tr>
<td>9.00</td>
<td>79VQ</td>
<td></td>
<td>EV3</td>
</tr>
<tr>
<td>11.00</td>
<td>67PG</td>
<td></td>
<td>EV4</td>
</tr>
<tr>
<td>12.50</td>
<td>587G</td>
<td></td>
<td>EV5</td>
</tr>
</tbody>
</table>

**Fig. 2:** Example of OBU packet Format.

### 3.2 Routing in CCAR:

The event processing refers to a process that updates its snapshot clock when an event occurs. When an events are communicated with the aid of the messages, the message process need two types of routing: Table-driven and On-demand Routing. The third part refers to the context consistency detection, Image ID and Time to Live (TTL) and message retransmission count. TTL is optimal time limit required to transmit the message to the vehicles and to destination of an event. TTL varies depending on the Event. Start and end time can be varied, so the time period is variable. For better performance TTL can be broken down into smaller time slabs. To avoid confusion between the vehicles and at the same time to save the battery power of the RSU, if the destination does not service even after two time slabs, the destination needs to be changed by using the Message retransmission count. Fig 3 explains the pattern of routing behaviour with WMSN.

#### 3.2.1 Event Process:

When the data frames arrive, the RSU classifies the frames based on the Event ID.

**A. System Formulation:**

Let RSU\(_1\), RSU\(_2\), .. , RSU\(_n\) be n Units in the Road traffic environment, Ei be an event set with priority Pi, and lo and hi be the start and end of an event, respectively. The packet format of Event process is in Table2.
The event $E_i$ is modeled as an interval. Note that RSU communicates with each other only by means of message, and the communication delay is finite but unbounded.

### 3.2.2 Message Process:
Routing the images or video data captured from road traffic without delay is a tumultuous task. Data is categorized as Normal, Priority data. For instance, Normal data are Traffic information, Location of Vehicle and Priority data are accident and fire. The RSU Works in two modes, one is Normal and the other is Priority Mode. In the Normal mode all the wireless communications transfers the data in the usual fashion and in the priority mode the transmissions are based on priority.

In this paper we propose Hybrid Routing, which combines characteristics of both reactive and proactive routing protocols to make routing more scalable and efficient. If RSUs are close to each other then table driven routing is implemented and if they are far off, on demand routing is used.

![Pattern of routing behaviour with WMSN](image)

**Fig. 3:** Pattern of routing behaviour with WMSN.

**Table Driven:**
When the Event is detected by OBU or RSU then the source RSU checks its table..If the Destination node ID is in Minimum distance the Table driven routing is initiated. It is by notifying the number of Hops in the table of Source RSU. If it is less than 5 , then table driven routing is chosen. Direction is decided by comparing with the neighbour RSU table’s hops, and a path with minimum value and the path direction with Accessible ID in the RSU Table. Since all the RSUs are static, it is easier to obtain the table information from its neighbours. So the process is speeded up to a great extent. Based on Event ID the requirement is automatically selected and it gives the Destination RSU ID. The Table Driven Routing information is explained in Table 3.
The packet transfer between source and destination RSUs is carried out with the packet information such as Source RSU Id, Time, Event ID and DRSU ID. The packet format is as in Table 4.

### Table 4: Packet format in Table driven Routing

<table>
<thead>
<tr>
<th>Event ID</th>
<th>Accessible ID</th>
<th>D-RSU ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ev4</td>
<td>Police</td>
<td>P12</td>
</tr>
</tbody>
</table>

**On demand Routing:**

If the number of Hops is myriad, then the on-demand routing is initiated. Routing is by path Discovery and Path Maintenance. Path Discovery is by RREQ, RPLY Messages. In event driven routing, packet with an end to end delivery and reliability is designed for selecting a path based on the characteristics of each node such as: (i) Energy consumption, (ii) Success ratio of the node. The energy consumption is based on a residual value a node and the success ratio of the node is calculated by Habitual information, which requires the history of the transmissions of the node and it is found by (1) Transmission Speed, (2) Sensor features and (3) Success rate.

The transmission speed is the ratio of power and the number of transmissions. They depend on Link quality and distance between the nodes. Due to static topology of sensor network, the distance is same; speed can also be calculated as distance/time whereas the link quality depends on Channel behaviour in multipath environments. The sensor features depict the configuration of the node which may be a high-ended version, and also the time of deployments. Based on an ID, a value is assigned to the configuration. For example, ID=3 denotes High Memory, ID=2 for Medium & ID=1 for Low. The success rate is calculated as the number of packets received without the packet being dropped. The packet format in on demand routing is in Table 5.

### Table 5: Packet Format in On demand Routing

<table>
<thead>
<tr>
<th>Snapshot Time</th>
<th>S-RSUID (RSU2)</th>
<th>S-IP Addr</th>
<th>Event ID</th>
<th>D-RSUID</th>
<th>D-IP Addr</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:00</td>
<td>67PG</td>
<td></td>
<td></td>
<td>P12</td>
<td></td>
</tr>
</tbody>
</table>

**3.3 Context Consistency:**

The consistency of the process is weighted by the time factor. Whenever an event occurs, a signal is transmitted to the destination via RSUs. The optimal time for the destination to service the request is TTL (time to live). TTL of an event is compared with Event Serviced Time (EST) and Round Trip Time (RTT).

Event time can be broken down into smaller time slabs for easy analysis. The exact time at which the destination services the request is noted as Event Serviced Time (EST). The total time taken for the signal to travel from the source to the destination and back to the source (as an acknowledgement for the service done by the destination after service is completed) is considered as the Round Trip Time (RTT).

The Fig 4 explains the state diagram, in which, when the event occurs, it is transmitted to the nearest RSU called as RSU₁ and transfer the packet to the destination RSU₂, depend on the Event ID.

The time taken for transmitting the packet from RSU₁ to RSU₂ is Event Serviced Time (EST), represented in Blue line. After receiving the packet RSU₂ acknowledges to RSU₁. Then the service made by RSU₂ reaches RSUs. The time taken for the acknowledgement and the arrangement is denoted as the Round Trip Time (RTT). (Marked in Pink Line.). For instance: when a car accident takes place at street 1, the RSUs of the particular street, after comparing the direction and efficient path selection criteria among themselves, chooses the most efficient path by any of the routing methodologies. TTL time slabs are fixed prior to sending the signal to the destination.

Let the optimum TTL for the event be taken as 6 minutes. The time slabs are

- Minute 1-3: time slab 1
- Minute 4-6: time slab 2
Case 1: If the information is sent to the destination 1 and service is started within the time slab 1, an acknowledgment (ACK) is sent back to the source (RSUs). The start of the service and end of service is noted as the Event service time (EST). RTT is calculated as end time of the event, after the arrangements made by the destination (RSUd) and reach to the source (RSUs).

If RTT <= TTL
Message retransmission count (MRC) = 0 // Stop transmitting the packet to other OBU’s and to RSU’s because MRC=0

Case 2: The information is sent to destination 1 and snapshot clock is started. If destination 1 does not respond to the request within Time slab1, RSUs in street 1 enter critical phase, by setting the value in the Message retransmission count (MRC). Then consider the next viable destination and also the most efficient path to reach that destination.

Case 3: If destination one fails to respond within time slab1, but responds after RSU enters the critical phase, then the process to determine the next viable destination and the most efficient path to reach the destination, is terminated.

In case 2 & 3 RTT is based on time need to find the other destination.
If RTT > TTL then
Message retransmission count (MRC) = + 1

Algorithm:
Input: RSU = {RSU1, RSU2, . . . , RSUn}, in the traffic System
EQ[i] be an event queue;
TTL[i] be an Optimum time interval for a event
EE[i], pairs of events which have communication with each other;
S[K], a list of snapshot timestamps;
Max hop: 5
Output: A set of events occurred in RSU_i transferred to the Destination with minimum delay.

begin
/* When an event ei occurs at RSUi */
if ei occurs in RSU_i at timestamp k with id is e_id .Si[k]

Event process ()
{
EQ[i].push(Si[k], e_id, pr_i) // push Time, Event ID, Priority into Event Queue
};

Message process ()
{
Select SRSUID_{1,i+1,i-1} // select the Source RSU’s Neighbors
//Check the no of hops from the table
SRSUID_{a} ( SRSUID_{i+1,i-1} ), ( No of Hops)
// Table driven Routing
If (SRSUID_{a} No of Hops) < Max hop
//Select Table driven Routing
//Compare the hops from No of Hops in the Table and choose the minimum hop.
Node = Min(SRSUID_{a}, No of Hops, SRSUID_{i+1}, No of Hops, SRSUID_{i-1}, No of Hops)
//Select Direction Based on Access ID
Choose Nexthop= Node . Access ID
(RSU_i, e_id, Si[k])
Else
// On Demand Routing
Path discovery () // Based on (i) Energy consumption, (ii) Success ratio of the node
Path reply ()// Choosing the path based on discovery.
// packet forwarding in On demand
RSU= (sk[i], S-RSUID, S-IP Add., Event ID, D-RSUID, D-Ip Add.)

Context Consistency()

TTL[i].push(eid[i], Si[k], Et = Si[k] + m); m is Maximum Time period of the Event.
EST[i] = Ack[RSU] → RSU, + Service(RSU) → RSU
RTT[i] = Ack(RSU) → RSU, + Service(RSU) → RSU
If RTT, <= TTL[i]
Message retransmission count (MRC) = 0
Else
Message retransmission count (MRC) = + 1

IV. Comparative Studies between GPS in VANET with RSU in MANET:
The scenario in Fig 5(a) explains, when the accident occurs, the event is transmitted to GPS satellite and it give the information to Hospital for the arrangement even though the source and destination are in fewer distance .But in the Fig 5(b) the Event is transmitted in Minimum number of Hops. Following are the issues taken for consideration in Table6 between GPS and RSU of WMSN while transmission and receiving of the Event

Fig 5(a) VANET Routing in Traffic
Fig 5(b) WMSN Routing in Traffic

Table 6: The comparison between GPU and RSU.

<table>
<thead>
<tr>
<th>Issues</th>
<th>GPS</th>
<th>RSU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>Licensed</td>
<td>Licensed Frequency (5.85-5.925 GHz)</td>
</tr>
<tr>
<td>Transmission Range</td>
<td>20m to 30m</td>
<td>300m</td>
</tr>
<tr>
<td>Latency</td>
<td>Based on region condition and signal strength and Latitude</td>
<td>4 ms to 5 ms</td>
</tr>
<tr>
<td>Path Loss</td>
<td>$P_r(d) = \frac{P_i G_t G_r h_i^2 h_r^2}{d^4 L}$ (180 db for 20000 Km)</td>
<td>$L_{errory}(dB) = 10 \log \left( \frac{d^4 L}{h_i^2 h_r^2} \right)$</td>
</tr>
<tr>
<td>Interference</td>
<td>Co -channel</td>
<td>Efficient Channel interleaving</td>
</tr>
<tr>
<td>Distance</td>
<td>20.000 Km in Height</td>
<td>500-1000 Km, Cluster Area</td>
</tr>
<tr>
<td>Handoff Mechanisms</td>
<td>From Access point to Access Point</td>
<td>No Handoff Mechanisms</td>
</tr>
<tr>
<td>Remote Terminal Gateway</td>
<td>From Earth to Satellite</td>
<td>Not Required, 802.11p standard used</td>
</tr>
<tr>
<td>Map</td>
<td>3-D Map is required</td>
<td>Not Required, Uses Table driven, On demand Routing</td>
</tr>
</tbody>
</table>
V. Conclusion:
The WMSN used in traffic surveillance, thus realizes a fruitful synergy in support of RSU for a number of application scenarios, such as surveillance and monitoring of remote areas, emergency communications. By using Context Consistency Aware Routing for Smart cities (CCAR) algorithm, the Events are prioritized, Route dissemination process is streamlined by hybrid routing and Consistency of the Context is accurately estimated. The future work of this paper can be extended with research activities entitled “The role of satellite in future sensor networks.”

REFERENCES


