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A Novel Methodology for Traffic Monitoring and Efficient Data Propagation in Vehicular Ad-Hoc Networks

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Abstract: *A vehicular ad hoc network is an emerging technology, however some challenging issues need to be resolved. In recent years, road congestion and traffic related pollution have a large negative social and economic impact worldwide. For better public transport, strategic planning, traffic monitoring is required to cut pollution and congestion. One of the important attributes of traffic data is the interval between the time that the data are generated by a vehicle on a particular road and the time that the data is made available to the user as a query response and also to select the fastest route to a destination in a reliable manner. To address these issues, this work focuses on two routing algorithms for VANETS 1) Delay bounded greedy forwarding(D-Greedy) 2)Delay bounded minimum cost forwarding (D-MinCost). The first proposed algorithm (D-Greedy) exploits local traffic conditions, i.e., information about the speed and density of cars at the road segment that it currently traverses. The second algorithm (D-MinCost) assumes knowledge of global traffic conditions, i.e., statistical information about the speed and density of cars on every road segment of the city. This work explores on the current traffic conditions on that road segment. Also a framework is proposed for vehicular networks that jointly optimizes the two key processes associated with monitoring traffic i.e. data acquisition and data delivery.*
Keywords: *Ad hoc network, data muling (DM), multihop (MH) communication, routing, sensor participation, traffic monitoring, vehicular ad hoc networks (VANETs), vehicular networks.*

I. Introduction

Recent years have witnessed a growing interest in the applications of Vehicular Ad Hoc Networks (VANETS). Of particular interest are the applications in the deployment of *ambient traffic monitoring* conditions, wherein vehicles equipped with the Global Positioning System (GPS) detect local traffic and periodically report it to one of the stationary roadside units dispersed throughout the city. These units are referred to as access points (APs) and act as gateways to the city's traffic-monitoring center (TMC) and the outside world.

One of the most important attributes of traffic data is *freshness*, i.e., the interval between the time that the data are generated by a vehicle on a particular road and the time that the data is made available to the user as a query response. Informally, data freshness indicates how stale the data are and to what extent they can be used to estimate trip times or to select the fastest route to a destination in a reliable manner.

We aim at minimizing the bandwidth utilization of a traffic monitoring system while adhering to user defined data freshness requirements. Applications could widely vary in their requirements for data freshness; for example, an emergency response application, e.g., an ambulance coordination service, has stringent constraints on data freshness in the order of a few minutes. On the other hand, a road maintenance company that works overnight could tolerate data staleness of tens of minutes to decide how to plan road repair work.

Thus, our high-level goal is to design an *ambient traffic monitoring* system that minimizes bandwidth utilization while adhering to user-defined data freshness requirements and also it focuses on undesirable communication overhead. Because our main goal is to reduce the communication cost associated with traffic-monitoring. To achieve this goal, the two system aspects that significantly impact both data freshness and bandwidth utilization: 1) data acquisition and 2) data delivery. The list is as follows

1) A novel problem is formulated in the context of ambient traffic monitoring, i.e., minimizing the communication cost required to monitor traffic while providing deterministic guarantees of data freshness.
2) Two novel delay-tolerant routing algorithms for vehicular networks are proposed i.e., ***delay-bounded greedy forwarding (D-Greedy)*** and ***delay-bounded minimum-cost forwarding (D-MinCost)***, which leverages locally available information about traffic and global traffic statistics to reach forwarding strategy decisions that, minimize communication.
3) A framework is prepared for a vehicular network that jointly optimizes the two key processes associated with monitoring traffic, i.e., data acquisition and data delivery.

4) The evaluation is done using MATLAB tool.

The figure 1 shows the VANET architecture which consists of GPS, RSU and vehicles.

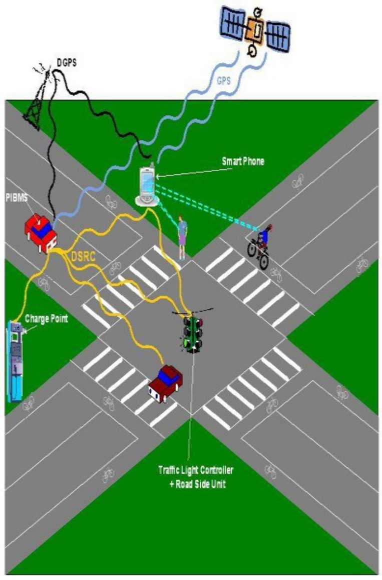

Figure 1: VANET Architecture

II. Related Work

Data dissemination in VANETs can be used to inform drivers or vehicles for traffic jams and to propagate emergency warning among the vehicles (incident or accident) to avoid collisions. In India alone, there are around 400,000 road accidents with 90,000 fatal accidents. Indian roads struggle with problems of traffic flow and instability.

We can save lots of lives, money, and time by forewarning appropriate information to the driver or vehicle regarding congestion and traffic management. Number of innovations in safety, comfort, and convenience have already made today's vehicle a very different machine than it was in the past days. Now a new technology characterized by proliferation of low-cost wireless connectivity and distributed peer-to-peer cooperative systems, is changing the way in which next generation vehicle will evolve. So data dissemination in VANETs plays important role for safety and non-safety applications.

VANETs are based on short-range wireless communication. The Federal Communications Commission (FCC) has recently allocated 75 MHz in the 5.9GHz band for licensed Dedicated Short Range Communication (DSRC).VANETs can be divided into two main areas: Safety applications (e.g. collision warning and work zone warning) and non-safety applications (e.g. traffic condition application and comfort application). For an example, if the vehicle has crashed on the highway, the emergency information can be propagated as soon as possible to inform the vehicles behind the accident for the purpose of safety of other vehicles, might be caused due to this accident.

The second area receiving direct benefit is relevant to transportation traffic control. The immediate benefit from VANET is to improve the efficiency of traffic system. Information about traffic jam can be acquired in real-time so that drivers heading towards the congested area can receive it with sufficient time to choose alternate routes. Toll roads can be automatically paid without the installation of additional hardware to a vehicle. Traffic signals equipped with communication equipment can be used to more accurately control intersection traffic.

Now non-safety applications, for example if a gourmand can easily find some suitable restaurants by using the location based service through VANETs and also useful local advertisements and announcements can be delivered to travelers, such as sale information at a departmental store, the available parking lot at a parking place, the room availability and price at a hotel, the menu at a restaurant. With the rapid applications of VANETs, especially for the safety applications, it may be time dependent. Thus, the information must be sent to other vehicle quickly. For the information dissemination in VANETs, we have to consider the different scenarios or different communication patterns. Node mobility, extreme network density and changing topology from urban gridlock to rural traffic and the rapidly changing information needs moving vehicles make VANETs harsh and demanding networks.

We consider the problem of data dissemination in VANETs, where (1) the vehicular network consists of multitude of data sources and data users; each vehicle is potentially a data source and user at the same time and (2) diverse types of applications, such as traffic management, situational awareness, and commercial services share the same networking infrastructure (RSUs etc.). The aim of data dissemination is to utilize maximum network resources to serve the data needs of all users. Each vehicle participating in the VANET periodically produces reports regarding the traffic condition.

Researchers and automotive industries are envisioning the deployment of *ambient traffic-monitoring applications*, where vehicles equipped with the Global Positioning System (GPS) detect local traffic and periodically report it to one of the stationary roadside units dispersed throughout the city. These units are referred to as access points (APs) and act as gateways to the city's traffic-monitoring center (TMC) and the outside world.

Important attributes of traffic data is *freshness*, i.e., the time that the data are generated by a vehicle on a road and the time that the data is made available to the user as a query response. Depending on the expected rate of change in traffic conditions, users may have different freshness requirements for different parts of the city or for different times of the day. It is crucial that the ambient traffic-monitoring application provides deterministic guarantees that the available traffic data satisfy the specified freshness requirements.

At the same time, the ambient traffic-monitoring application will share bandwidth resources with various applications that run on the same vehicular ad hoc network (VANET), e.g., applications that provide Internet access to passengers, commercial applications that flood advertisements about nearby stores, and safety applications that provide drivers with emergency braking services. Thus, our goal is to design an ambient traffic monitoring system that minimizes bandwidth utilization and also takes care of data freshness. To achieve this goal, we investigate the following two aspects of traffic monitoring, both of which significantly impact both data freshness and bandwidth utilization: 1) data acquisition and 2) data delivery.

VANETs have some unique characteristics not shared by other types of MANETs:
1. VANETs track position of vehicles moving at high speed.
2. Mobility patterns are somehow predictable as movement is constrained by road infrastructure. In some situations such as highway traffic, the mobility patterns become highly predictable.
3. Large coverage area. Vehicles travel over long distances and traffic information may be useful to vehicles hundreds of miles away.
4. Power consumption is not a major concern. Vehicles are mobile power plants.
5. Vehicles have a high cost and therefore can be equipped with additional sensors without significantly impacting the total cost.
6. VANET's topology is extremely dynamic as vehicles go in and out transmission range quite rapidly.
7. Vehicles travel long distances in a small amount of time when compared to other mobile networks.

III. Proposed System Design

Our motivating example is the ***ambient traffic sensor application*** wherein vehicles are equipped with sensors that detect accidents, road faults and traffic congestion. On detection of an interesting event, vehicles attempt to notify the city's traffic monitoring center, by sending the information to one of the stationary roadside units dispersed in the city. These are referred to as *access points (APs)* and act as gateways to stream traffic information through a fixed network to the outside world.

We note that messages may have very different priorities, and thus delay thresholds until they are delivered to one of the APs. For example, information about a serious accident has higher priority than information about a road fault. The former must be delivered to one of the APs much faster than the latter, since it calls for immediate assistance from fire, hospital or police departments. It is therefore vital that packet forwarding algorithms are designed to prioritize packets based on their urgency and deliver them within user defined delays.

The goal is to design algorithms that try to optimize bandwidth utilization, by being frugal in wireless packet transmissions. To do so, we plan to leverage knowledge of traffic information on different parts of the city. Our proposed algorithms are traffic-informed and they adapt their behavior depending on the traffic density and the average vehicle speed on different road segments.

The key to achieve this goal is to take into consideration statistics of vehicle density and speed in various parts of the city. We carefully study the tradeoff between the competing requirements for timely data delivery and low bandwidth utilization.

We propose two novel algorithms, D-Greedy and D-MinCost that exploit traffic information to forward packets to the most convenient access point. D-Greedy exploits only local traffic information, whereas D-MinCost leverages traffic information about the entire city. Unlike existing vehicular-assisted forwarding algorithms [16], D-Greedy and D-MinCost do not try to minimize delay of packet delivery. Their goal is to minimize the number of packet transmissions required to satisfy packet-specific delay thresholds.

The proposed work consists of two system aspects which impact on both data freshness and bandwidth utilization they are-data acquisition and data delivery which are as follows:

3.1 *Data Acquisition*

Data acquisition refers to the sampling of road traffic information by passing vehicles. High sampling rates can be achieved by having vehicles participate in the sampling process and generate traffic information messages with high frequency. The lower the data acquisition period (DAP) is, the fresher the traffic data that become available for each road, but the larger the number of traffic messages propagated through the network.

3.2 *Data Delivery*

Data delivery refers to the propagation of traffic messages from the originating vehicle to one of the APs dispersed in the city. Traffic messages can be delivered either by wireless multihop forwarding (MF) or by physically carrying messages at the vehicle's speed towards an AP. We propose hybrid algorithms that carefully combine MF and data muling (DM) to achieve a desirable delivery delay. Clearly, the lower the data delivery delay (DDD), the fresher the traffic data available at the APs, but the higher the use of MF, and thus, the higher the communication cost. The block diagram of system is shown in figure 2.

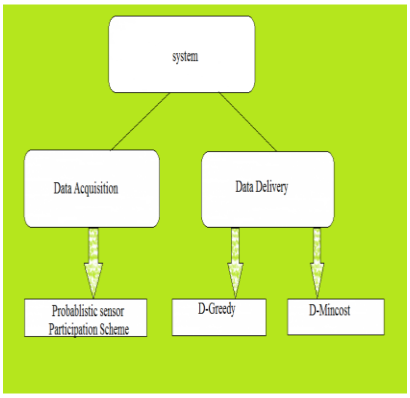

Figure 2: Block diagram of proposed system

IV. Proposed System Algorithms

The proposed algorithms leverage local or global knowledge of traffic statistics to carefully alternate between the Data Muling and Multihop Forwarding strategies, in order to minimize communication overhead while adhering to delay constraints imposed by the application.

We present two novel routing algorithms for VANETs, *Delay-bounded Greedy Forwarding (D-Greedy)* and *Delay-bounded Min-Cost Forwarding (D-MinCost)***.** The goal of algorithms is to deliver messages originating in vehicles to an access point with bounded delay while minimizing the number of wireless transmissions.

D-MinCost requires knowledge of *global traffic conditions*, i.e. statistical information about the speed and density of cars on every road segment of the city. In this work we do not study the precise process of maintaining a fairly accurate set of urban traffic statistics but rather assume that, when in the vicinity of access point, vehicles can update the preloaded street map with the latest statistical information. D-Greedy, on the other hand, requires no such knowledge. It only relies on local information, i.e. vehicle speed, to make forwarding decisions.

Our algorithms intend to minimize the number of transmissions while forwarding a message to an access point within the message-specific delay threshold. Two forwarding strategies used are:

a) Multihop Forwarding, which refers to the aggressive forwarding of messages to vehicles that are better positioned to deliver them to an access point.

b) Data Muling, which refers to buffering messages in local memory and carrying them at the vehicle's speed.

4.1 *Delay-bounded Greedy Forwarding (D-Greedy):*

The D-Greedy algorithm defines a forwarding strategy that assumes no knowledge of traffic information beyond node speed, which can be derived locally from the available location information. D-Greedy assumes that the best path to an access point is the shortest one. i.e, the path that minimizes the sum of the lengths of the edges on the directed graph *G* that abstracts the street map.

When multiple APs exist, the algorithm selects the closest one, i.e. the one on the shortest path beginning at the vehicle's location. Each vehicle maintains a neighbor list by periodically broadcasting beacons. A beacon message contains the unique vehicle identifier (*id*) and the length of the shortest path between the vehicle's current location and the location of the closest access point
(*distToAP*). *distToAP* is computed by running a single invocation of Dijkstra on *G* just before broadcasting a beacon. As soon as a vehicle senses an event and generates a new message, the message is assigned a delay threshold value (*TTL*) and is considered to be useful only if delivered before *TTL* has elapsed.

A. Greedy Strategy Selection

Vehicles periodically iterate through their buffers and make greedy decisions about the strategy that will be used for forwarding each message to the closest AP. The decision depends on the remaining delay budget (*TTL*) until the message expires as well as on the distance to the closest AP (*distToAP*). Since global traffic information is not available, D-Greedy assumes that the remaining message delay budget can be uniformly distributed among the edges that compose the shortest path to the AP. Each edge on the path is allocated a delay budget that is proportional to its length. The algorithm periodically monitors the forwarding progress of each message; as long as the actual time spent by the carrying vehicle that travels along an edge does not exceed the delay allocated to that edge, the Data Muling strategy is selected for the message. Otherwise, the algorithm assigns the Multihop Forwarding strategy to the message.

The figure 3 shows that there is a source vehicle and a access point.

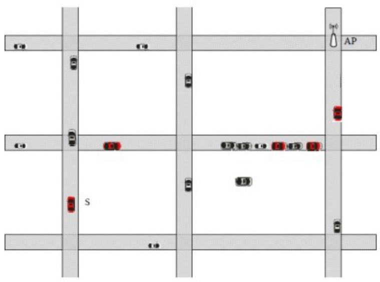

Figure3: D-Greedy strategy

Let *distToInt* be the remaining length, until the next intersection, of the current street segment on which the vehicle is traveling. *distToAP* denotes the current shortest path distance from the closest AP. *U* the average speed of the vehicle calculated during a *k*-second historical window. D-Greedy computes the available delay budget *Del* for forwarding the message along the current edge up to the next intersection as follows:

$$Del = TTL \times \frac{distToInt}{distToAP}$$

D-Greedy calculates the expected delay if the Data Muling strategy were to be used to carry the message to the next intersection

$$Del_{DM} = \frac{distToInt}{u}$$

$$Del_{DM} \leq Del$$

If then the algorithm opts for the Data Muling strategy. Otherwise, the Multihop Forwarding strategy is chosen. In this case, the message is forwarded to the neighboring vehicle in range that is closest to the AP and it is deleted from the node's buffer. There are two extreme cases in which a vehicle does not apply the selected forwarding strategy for the message. When there is no better-positioned neighbor node to forward the message than the current node, messages that were originally assigned to use the Multihop Forwarding strategy switch to Data Muling. Similarly, if the carrying vehicle is moving away from the closest AP, messages that were originally assigned to use the Data Muling strategy switch to the Multihop Forwarding strategy until a vehicle traveling towards the AP is found.

Figure 4 indicates the D-min cost strategy which shows delay and cost in terms of Data Muling and Multihop forwarding. Also it shows the shortest path to reach the access point and minimum cost required to reach AP.

4.2 Delay-Bounded Minimum Cost Forwarding (D-MinCost)

Our second proposed algorithm leverages the knowledge of global traffic statistics, i.e. estimated values of average vehicle speed *u* and density *d* for all edges of the street graph *G*. Based on this information, D-MinCost computes bandwidth-efficient delay-constrained paths for every message in the node's buffer. In the graph that abstracts the street map, edges represent road segments and vertices represent road intersections. We would like to annotate each edge with two metrics:

1) Cost (C), representing the number of message transmissions along the edge.
2) Delay (*Del*), denoting the time required to forward a message along the edge.
However, the cost and delay of forwarding a message along an edge depends on whether we are using the Data Muling strategy or the Multihop Forwarding strategy. For edges associated with the Data Muling strategy:

$$Del_{DM} = \frac{\ell}{u},\ C_{DM} = 1$$

Where ***l*** denotes the length of the edge and the $\overline{u}$ average vehicle speed along that edge. We fix the communication cost of the Data Muling strategy to 1 message transmission regardless of the segment length. The reason is simple: the vehicle carries the message along the entire road segment, and in the worst case, transmits it only once upon reaching the intersection. For edges associated with the Multihop Forwarding strategy, we must first check whether Multihop is feasible on the road segment. For wireless communication range *R*, Multihop Forwarding is an available option if $\ell > R$ and, $\overline{d} \geq \frac{\ell}{R}$ where *d* is the average vehicle density for the edge in question.

$$C_{MH} = \frac{\ell}{R},\ Del_{MH} = C_{MH} \times q$$

q denotes the time required for the node to check its neighbor list and identify the best next hop.

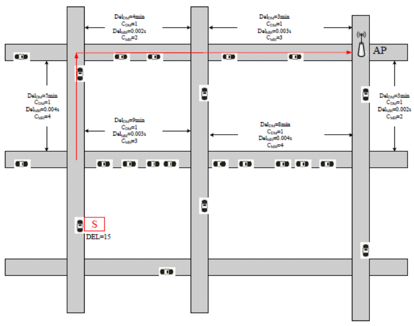

Figure 4: D-MinCost Strategy

V. Simulation & Results

Simulations are compiled with MATLAB tool version 7.10.0.499(R2010a) .

Figure 5

Figure 5 shows the shortest path from source to destination. Here the source is node 1 and destination node 7.The total numbers of nodes are 30.After performing the dijkstra's shortest path algorithm we got the total cost as 4.

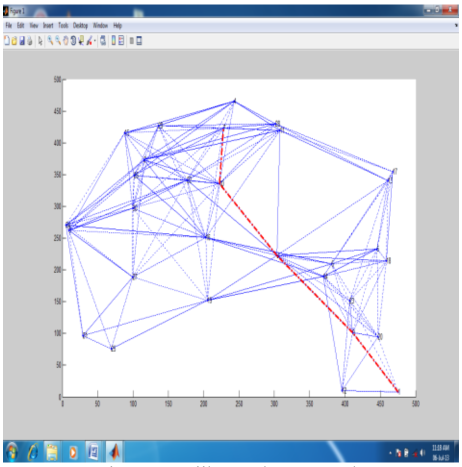

Figure 5: Dijkstra shortest path

path =1 9 3 10
total Cost =4

Figure 6

Figure 6 shows the situation of multiple paths. The numbers of nodes present in the graph are 70.Graph shows the two best possible paths from node 1 as source and node 15 as destination.

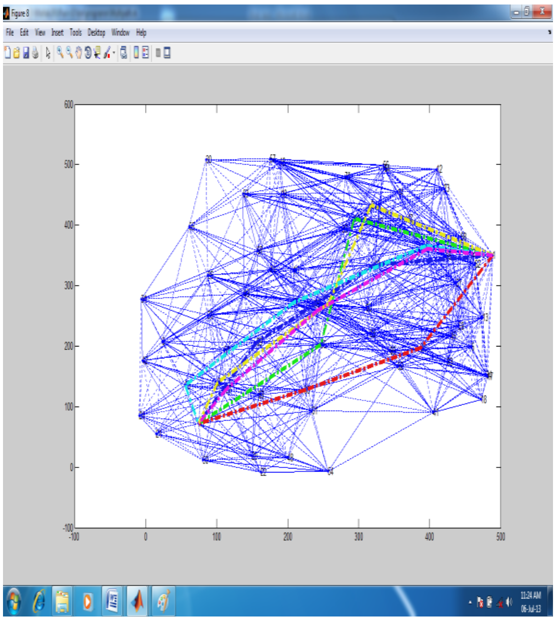

Figure 6: Multipath from source to destination

Figure 7:

Figure 7 shows the best path from source as node 1 and destination as node 15 is path= 1 9 7 27 15 and the cost is 4

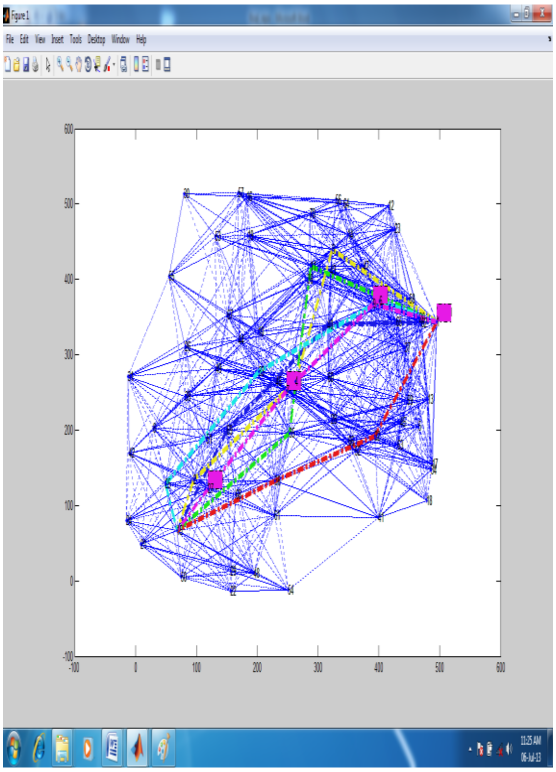

Figure 7: Highlighted multipath from source to destination

Figure 8:

Figure 8 shows the shortest path from node 1 and node 12.Also the result shows the total distance from source to destination and the number of iterations performed. Here total distance=1947.3766 and number of iterations performed are 1740.

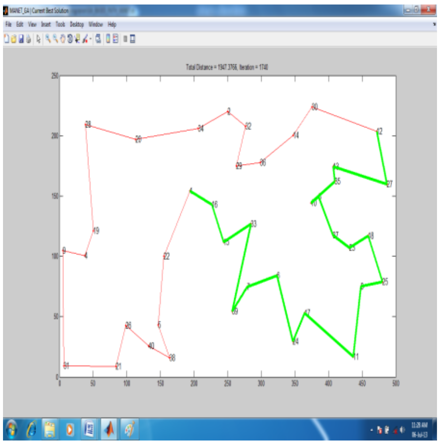

Figure 8: Shortest Path

Figure 9:

Figure 9 shows the node locations after the simulation and also it shows distance matrix, total distance and the best solution history.

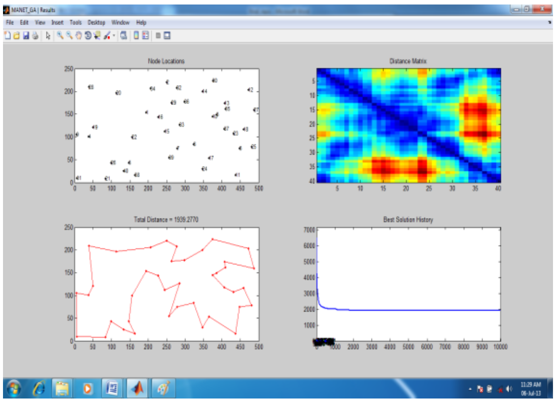

Figure 9: Node location, total distance, best solution, distance matrix

Figure 10:

Figure 10 shows the path from source=1 and destination=12.

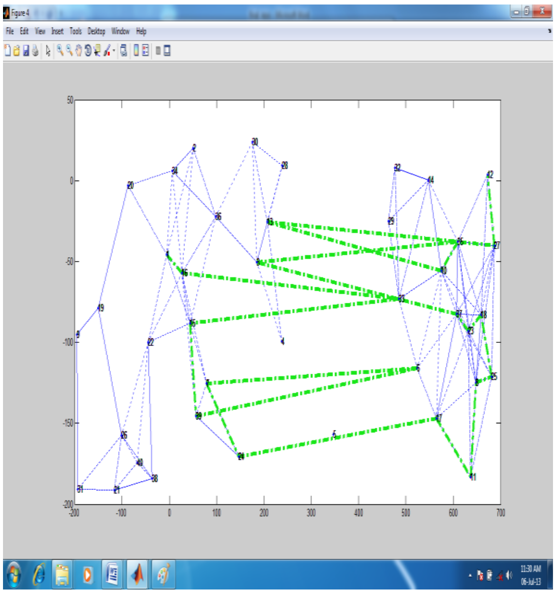
Fig10: Path formed

VI. Conclusion and Future Scope

In this work the problem of minimizing the communication incurred by traffic monitoring systems while providing deterministic guarantees of information freshness is defined. The proposed algorithms ensure that it will be utilized in both key processes associated with monitoring traffic i.e., data acquisition and data delivery. For data delivery, the following two novel packet-forwarding schemes for vehicular network scenarios are proposed, which route messages towards fixed infrastructure nodes: 1) D-Greedy and 2) D-MinCost. A framework is proposed that jointly optimizes the data acquisition and data delivery stages in the traffic-monitoring system. In this work, a busy urban scenario is considered, where the wireless medium is expected to be congested throughout.

Because of limited time constraint we are unable to include all the features of VANETS and also we are not providing up to date information. The framework for weather information can be incorporated in future using this work. Vehicle-to-Vehicle(V2V) and Vehicle-to-Roadside(V2R) Communication can bring out the following achievements in future like presence of obstacles on road, emergency braking of a preceding vehicle, information about blind crossing, school proximity, railway crossing, entries to highways, high speed internet access, electronic toll collection, parking space locater in cities, information about nearest petrol pump etc..

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