VANET: Application of Mobile Communications in Road Traffic

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ABSTRACT
In day to day life we are facing major problems of traffic jam, road accidents, etc. This is an attempt to solve this problem using mobile communication The use of mobile devices like PDA, Mobile phones, laptops have grown immediately over the last few years, as these devices have become an indispensable part of most people's life. In the recent years, vehicular networking has gained a lot of popularity among the industry and academic research community and is seen to be the most valuable concept for improving efficiency and safety for future transportations. Today's cars already comprise some, but tomorrow's cars will comprise many wireless communication systems and mobility aware applications. Music, news, road conditions, weather reports, and other broadcast information are received via digital audio broadcasting (DAB) with 1.5 Mbit/s. For personal communication, a universal mobile telecommunications system (UMTS) phone might be available offering voice and data connectivity with 384Kbit/s. For remote areas, satellite communications can be used, while the current position of the car is determined via the global positioning system (GPS). Cars driving in the same area build a local ad-hoc network for the fast exchange of information in emergency situations or to help each other keep a safe distance. In case of accident, not only will the airbag be triggered, but the police and ambulance service will be informed via an emergency call to a service provider [7]. Taking into account the constant growth of automotive market and the increasing demand for the car safety, also driven by regulatory (governmental) domain, the potential of car-to-car connectivity is immense. The solution to above problem is VANET [6].

KEYWORDS
VANET, infostations, congestion, V2V, V2I, RSU, VOTING

1.0 ROAD TRAFFIC CONGESTION PROBLEM

Traffic congestions are formed by many factors; some are (somehow) predictable like

- Road construction
- Rush hour or bottle-necks and
- Unpredictable factors like accidents, weather and human behavior.

Drivers, unaware of congestion ahead eventually join it and increase the severity of it. The more severe the congestion is, the more time it will take to clear once the cause of it is eliminated or ameliorated. The ability for a driver to know the traffic conditions on the road ahead will enable him/her to seek alternate routes saving time and fuel. When many drivers have this ability, traffic congestions, specifically those related to localized incidents such as accidents or temporary disruptions will be less severe and only the vehicle in the immediate vicinity of the incident, at the time of the incident, will be affected. This would lead to a much more efficient use of our road infrastructure. Traffic congestions result from driver behavior and the lack of wide distance information. Current systems, such as helicopter traffic reports are effective because from the air we can get a good picture of a congestion area, where it starts, where it ends and how slow or fast is moving, however these reports require enormous resources and are therefore limited to major metropolitan areas. In order to provide drivers with useful information about traffic ahead a system must:

- Identify the congestion, its location, severity and boundaries.
- Relay this information to drivers within the congestion and those heading towards it.

These two requirements must be satisfied by any traffic congestion system. To identify the congestion an observer, like one riding on the helicopter, needs to see vehicles that are a long distance away from each other, and outside of each other's line of sight. A visual picture of the congestion can only be obtained from a vantage point, well above the road surface. For vehicles within the congestion to form their own picture of a congestion they need to collaborate using vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communication. Once a clear picture of the congestion has formed, this information needs to be relayed to vehicles away from the congestion so that vehicles heading towards it can take evasive actions avoiding further escalation its severity.

2.0 SOLUTIONS TO TRAFFIC CONGESTION PROBLEM

Most current navigation systems are static and do not provide traffic information. Route selection is based solely on static map data which leads to the system that fails to give the driver the most efficient route to his/her destination. In the last year or so, some of these devices have incorporated "real-time" traffic information to aid in route selection. Such "real-time" traffic systems such as the services provided from NAVTEQ and other commercial services today rely on humans and/or road infrastructure like traffic cameras and radars to maintain a central database of current traffic conditions. This limits their real-time accuracy and restricts its reach to major metropolitan areas. Monitoring traffic in this way, at all times, in all places is simply not cost-effective even in the most developed parts of the world. As an example, at the time of this writing, in New York City, a densely populated city of 305 square miles (790 km2) and 8 million inhabitants, only 81 traffic cameras were in place and they only provide visual information that still needs to be translated into congestion information either by humans or specialized software [11]. The main characteristic of current systems is that they are one-way: vehicles only receive information, usually through FM radio or satellite. Requiring vehicles to transmit data in real-time to a central location would require an enormous communications infrastructure not widely available today across major highways, specially outside the major urban areas of the most industrialized countries. Two-way communication systems such as OnStar™ rely on cell-phone communications which are not "always on" and are not designed for the volume of communications required by a real-time traffic-aware navigation system.

The work presented on this paper uses a distributed approach that uses vehicles themselves as nodes in a vehicular ad-hoc network (VANET) as well as data-gathering devices that collect the necessary information to determine current traffic conditions and disseminate it over long distances through the use V2V communications. By integrating this information into the vehicle's navigation system, the system will be able to provide the driver with traffic-aware routing recommendations using an efficient routing algorithm that takes into account traffic information. A distributed approach to traffic congestion detection is the most efficient approach because it provides a greater degree of reliability and flexibility and does not require a major investment in infrastructure as the costs are distributed among many drivers [12].

3.0 INTRODUCION-VANET

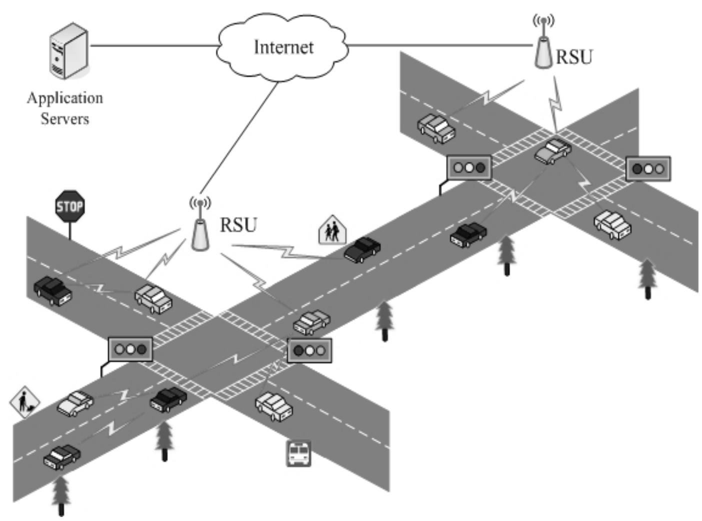
Automobile traffic is a major problem in modern societies. Millions of hours and gallons of fuel are wasted everyday by vehicles stuck in traffic. According to the Texas Traffic Institute, drivers in the US wasted 4.2 billion hours of time, 2.9 billion gallons of fuel, and a total cost of 78 billion dollars in 2005 due to traffic delays. Technology is at a point today in which vehicles themselves could be used to compile and analyze traffic data and relay it to the drivers in a format that will allow them to make smart decisions to avoid congested areas. Communications between vehicles can be achieved either through Vehicle-to-vehicle communications (V2V) and/or vehicle-to-infrastructure (gateway) communication (V2I) [9], [10]. VANET are a form of mobile ad-hoc networks (MANET) that provide communications between nearby vehicles and nearby fixed equipment. With the wireless technology becoming pervasive and cheap; several innovative vehicular applications are being discussed. We classify these applications into two main categories -

• **Safety Related**: [1], [9] Applications like collision alert, road conditions warning, merge assistance, deceleration warning, etc. will be classified under safety related applications where the main emphasis is on timely dissemination of safety critical alerts to nearby vehicles.

• **Internet Connectivity Related**: [2] Accessing emails, web browsing, audio and video streaming are some of the connectivity related applications where the emphasis is on the availability of high bandwidth stable internet connectivity While Infostations and 3G/4G primarily provide the vehicle to infrastructure(gateway) communication in the context of vehicular communication, VANETs assumes a more generic framework that includes both the vehicle to vehicle communication and limited V2I communication with higher emphasis on the V2V communication

VANETs Infrastructure

VANETs are a form of mobile ad-hoc networks to provide communications among nearby vehicles and between vehicles and nearby fixed equipment called Road-Side infrastructure Unit (RSU) [6]. To this end, special radios and sensors would be embedded within the car.



Many car manufactures and research institutions are investigating ways of establishing vehicular networks. Because of the flexible nature of Mobile Ad Hoc Networks (MANET), they represent an attractive solution for inter-vehicular communications. VANETs have some unique characteristics not shared by other types of MANETs:

- Vehicles move at high speed.
- 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.
- Large coverage area. Vehicles travel over long distances and traffic information may be useful to vehicles hundreds of miles away.
- Power consumption is not a major concern. Vehicles are mobile power plants.
- Vehicles have a high cost and therefore can be equipped with additional sensors without significantly impacting the total cost.

- VANET's topology is extremely dynamic as vehicles go in and out transmission range quite rapidly.
- Vehicles travel long distances in a small amount of time when compared to other mobile networks.

  The V2V communication infrastructure assumes the presence of high bandwidth with low latency. The radios typically operate on unlicensed band making the spectrum free. The most compelling application for V2V would be the safety related application since the latency requirements for these applications are very stringent. The V2V infrastructure in VANETs can provide low latency data dissemination from the point of impact to the nearby vehicles using short range radios.

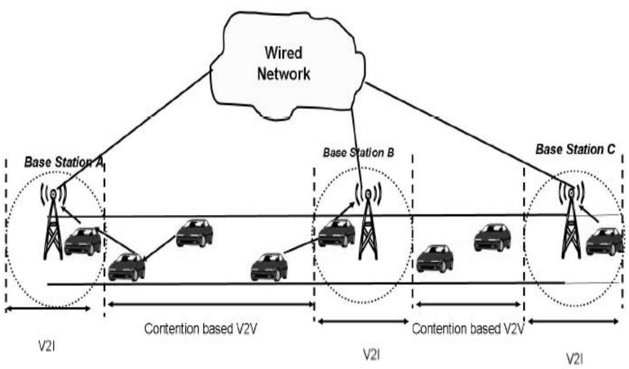


Fig. 1- Concept of V2V and V2I

Infostations

Infostations [5] is a wireless system concept that can provide isolated pockets of high bandwidth connectivity to the internet for mobile terminals. In the context of vehicular communications, Infostations are the wireless Access points deployed at specific locations in the road network to support V2I communication. Infostations technology envisions ultra-high-speed radios operating at 100s of Mbps or even Gbps rates, current generations of hardware using variants of the 802.11 standard are now providing bit rates in the tens of megabits per second, using compact, low-cost hardware. As pointed out in the definition, the connectivity is intermittent and can sustain high bandwidth with low latency. The use of wireless technologies that utilize the free spectrum(unlicensed band) reduces the cost per bit thereby making internet accesses through infostation extremely cheap. The most compelling application for Infostations is internet connectivity, esp. for file transfer and bursty data transfers. Since the connectivity is intermittent, Infostations cannot sustain interactive applications and these can definitely not be used for latency critical applications(safety applications).

Mobile Communication standards: 3G/4G

The Mobile communication standards have emerged from first generation to the third generation and the fourth generation Mobile communication standards are actively being researched. Figure 2 plots the Datarate Vs. Mobility (or Communication Range) trade-off. As can be seen from Figure 2

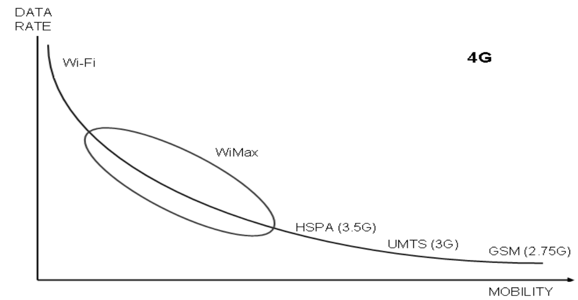


Fig. 2 Data Speed Vs. Mobility for wireless systems

Wi-Fi has the highest data rate(around 10Mbps) but absolutely no mobility support while GSM(2.5G) has the best mobility support but can only sustain data rates of upto 180kbps. Universal Mobile Telecommunication System (UMTS) [7] is one of the third generation cell phone technologies that is widely being adopted in the present day and it could support data rates of upto 384Kbps. In general, the trend in the mobile communication standards is towards improving the data rate and sustain as much mobility as possible. 4G, the future mobile communication technology proposes to provide a radically new design rather than incremental improvements over the prior mobile communication standards. 4G promises high data-rates with high mobility support and smooth handoff across heterogeneous networks. However, at present, we have no evidence that 4G is indeed going to fulfill all these objectives, and even if it does, it is not going to be cheap in the near future. So, for the purpose of further realistic discussion, we will limit ourselves to the widespread 3G technology. We can see that 3G networks have bandwidth constraints and inturn have higher latency with increased accesses. Since the spectrum under use is a licensed band, there is an increased cost per bit thereby making internet accesses more expensive than the infostation model. As we can readily see, there is an improved mobility support enabling more interactive internet applications

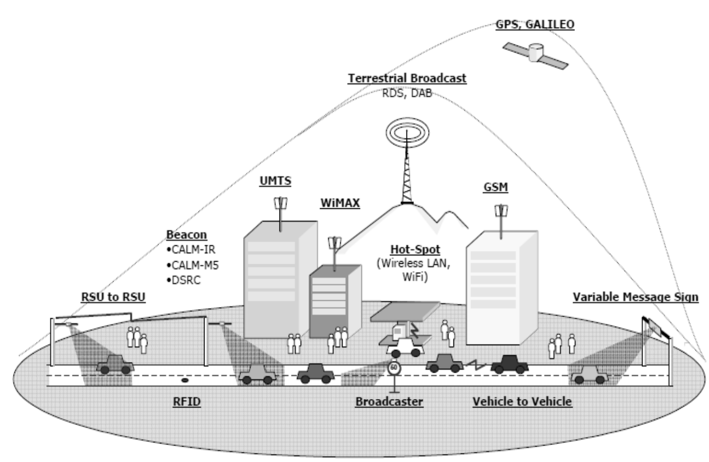


Fig 3 Involved Technologies in VANET

Proposed Algorithm: Vehicular Over-the-air Information Gathering (VOTING)

What is traffic congestion? Although this question may sound very simple, after all, we all have experienced traffic congestions in our own lives and when we are in one, we know it. However, as humans we have access to large amounts of information through all of our senses: we can see the vehicles around us, we know attributes of the road such as speed limit, road conditions, weather conditions, etc. For a vehicle mounted computer that only knows the vehicle location, speed and direction, it is a different story. To start with, the computer doesn't know what the intention of the driver is, if the car is going "too slow" is it because the driver wants it that way or because the there is something in the road (accident, large density of vehicles, bad weather) that's forcing the driver to go slow? The later gives us a natural definition for traffic congestion: An area of congestion is an area on which a large number of vehicles are going significantly slower than the drivers intend.

At the core of our research is the Vehicular Over-the-air Traffic Information Gathering system (VOTING for short) [3]. VOTING is based on a simple idea: decision by majority. A congestion area is formed when a large majority of vehicles going through a specific geographical area are going significantly slower than the maximum posted speed limit. Speed limits are available to the vehicle's computer via archival map information such as that used in today's vehicle navigation systems.

Vehicles transmit information every broadcasting interval. The broadcasting interval is fixed and equal for all participating vehicles, however, the algorithm does not require that vehicle's clocks are synchronized; each vehicle can transmit at a different time as long as the time between transmissions is reasonably close to that of other vehicles in the network. In other words, an accurate clock is needed; the clock from the GPS system would be a good candidate for keeping time in a practical implementation.

4.0 GENERAL IDEA

The detection of congestion areas in VOTING is done as follows:

- All vehicles broadcast their current location, speed and direction at fixed time intervals.
- A vehicle that is going "slower than normal" considers itself to be in a congestion. A vehicle that believes to be in a congestion will validate its congestion area with data received from other vehicles. This is where the name VOTING comes from: If the information received is consistent with the congestion, it is said to be in agreement. When the number of vehicles in agreement surpasses those in disagreement by a certain margin, and the congestion reaches a certain size, the congestion is then validated and broadcasted.
- Vehicles that are not in a congestion limit their participation to broadcasting their own information (location, speed and direction) and the congestion information they have received from other vehicles. They do not make any changes to congestion information.

These are the main characteristics of the VOTING algorithm:

- Vehicle raw information (location, speed, direction) is broadcasted and received by vehicles nearby. Raw information is never retransmitted. This minimizes bandwidth usage and eliminates the requirement for vehicle IDs.
- Only vehicles that are part of the congestion can characterize it and change congestion information. Vehicles outside of the congestion can only read it and re-transmit it.
- Speed measurements are taken as a moving average to eliminate stop-and-go noise.

Congestion information travels by hopping from vehicle to vehicle and is also carried by vehicles going in the opposite direction on the highway via delayed retransmission. Because congestions are intrinsically slow the small lag caused by this delayed retransmissions does not significantly degrade the accuracy of the system.

A vehicle going slower than normal is not on itself a cause for a congestion, the vehicle may be in the shoulder or disabled but not causing any major disruption to traffic around it. This type of "false congestions" are flushed out when other vehicles going in the same direction, going at normal speed "vote" against it, effectively invalidating the suspected congestion area and preventing it from being broadcasted to other vehicles in the network.

A vehicle that is in a real congestion receives multiple confirmations from vehicles nearby going also slower than normal allowing the vehicle to expand and validate its congestion area. Only after a suspected congestion area is validated by a reasonable number of vehicles it is then broadcasted. This reduces unnecessary network usage and false congestion from affecting the efficiency of the system.

Congestion areas may span longer than the transmission radius causing big congestions to be split. Vehicles believed to be in congestions use congestion information received from other vehicles to consolidate with its own congestion area producing a congestion area that encompasses its own congestion and overlapping congestions received from other vehicles.

5.0 FORMAL ALGORITHMS

1. Broadcasting [4]

Every broadcast cycle congestion information is updated before sending. Vehicle has location, speed, direction and timestamp

BROADCAST (vehicle, congestion, knownCongestions)
mayBeInCongestion ← vehicle.speed <
MinimumNormalSpeed
inCongestion ← **false**
agreement ← 0
if mayBeInCongestion **then**
    if congestion **is empty then**
        congestion ← new Congestion

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congestion.AddVehicle(vehicle)
agreement ← congestion.size / congestion.Disagree
inCongestion ← (agreement > **MinimumAgreementRatio)**
congestion.disagree ← 0
else
myCongestion ← **empty**
vehicle.timeStamp ← **CurrentTime**
knownCongestions.RemoveOld()
if inCongestion **then**
Radio.Broadcast(vehicle, congestion, knownCongestions)
else
Radio. Broadcast(vehicle, knownCongestions)
return vehicle, congestion, knownCongestions

2. Receiving [4]

The parameters correspond to the information received
RECEIVE(vehicle, congestion, knownCongestions)
if not (this.congestion is empty) then
if vehicle.direction = this.direction and
this.congestion.IsNear(vehicle) then
if vehicle.speed >MinimumNormalSpeed then
this.congestion.Disagree ++
else
ADD-ITEM (
this.congestion.vehicles,vehicle)
if not (congestion is empty) then
if this.congestion.Intersects(congestion) then
ADD-ITEM(
this.congestion.intersectingCongestions, congestion)
UPDATE-CONGESTION(
this.congestion.vehicles,
this.congestion.intersectingCongestions)
foreach c in knownCongestions do
Keep congestions in the same relative direction to the sender or going in the opposite direction
if c.direction != this.direction or
vehicle.locationthis - this.location = c.direction then
if c.Intersects(this.KnownCongestions) then
this.KnownCongestions.ReplaceIfNewer(c)
else
this.KnownCongestions.Add(c)

5.0 CONCLUSION

We have discussed the need of a system as a solution to road traffic problem. VANETs would turn out to be the networking infrastructure for supporting future vehicular applications. We showed that there are several challenges including security and privacy and that active research efforts are being undertaken to bridge the gaps required to make VANETs a reality. We finally discussed the counter claims that challenged the practicality of VANETs and showed that there are indeed strong reasons for vehicular applications to be deployed and that a pure V2V or V2I based solutions will not be sufficient and VANETs would indeed succeed in catering to these applications.

6.0 FUTURE SCOPE

In the future, cars will also inform other cars about accidents via the ad-hoc network to help them slow down in time, even before a driver can recognize an accident. Buses, trucks and trains are already transmitting maintenance and logistic information to their home base, which helps to improve organization (fleet management), and saves time & money. We can also think on air traffic and railroad traffic. Different problems can occur here due to speed. While aircraft typically travel at up to 900km/h and current trains up to 350km/h, many technologies cannot operate if the relative speed of a mobile device exceeds, e.g. 250km/h for GSM or 100 km/h for APMS [7].

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