ISSN (e): 2250 – 3005 || Volume, 07 || Issue, 09|| September – 2017 ||
International Journal of Computational Engineering Research (IJCER)

A review of Generalized DistributedArchitecture for Applications Development in VANETs

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ABSTRACT:
Vehicular ad hoc networks (VANETs) have a number of interesting applications to preserve road safety, notify usersabout changed road/traffic condition, handling post accident hazards and moreover service oriented applications to makethe travel convenient to the drivers.Use of common information format for diverse applications enables the applicationdevelopers to easily design flexible information dissemination system for new applications or add new features toexisting application. This paper introduces a common information format for various applications in VANETs. The maingoal of the paper is to design generalized distributed architectures for vehicular networks, which considers diverseapplicationdevelopmentscenariosandusescommoninformationformat.Theproposedarchitecturesenabletheapplication developers to flexibly disseminate information to affected or interested user. In this paper, we have given adetail description of each component of the architectures and how they communicate with each other. In future, we willimplementthe proposedarchitecture usingsuitablesimulator.

INTRODUCTION

Vehicular Ad-Hoc Networks (VANETs) technology is one of the mostemerging research areas increasingly considered on different issues anddevelopmentofroadsafety.Recently,vehiclesarebecomingmoreautomated, which are able to sense the surrounding environment andtheirchanges.Useofsuchinformationalongwithcommunicationbetween vehicles can create a fundamental building block of intelligenttransport systems (ITS) and can provide numerous application servicestoimprove safety andcomfort ofdriving[1, 2,3].

VANETshaveanumberofinterestingapplications:oneofthemisroadsafety applications such as accident warnings, red-light warnings andspeed limit. Another set of applications is service oriented applicationssuch as available parking places, fuel prices from local station, whichare mostly dynamic and not fixed with the route information of thevehicleasthesafetyapplication[4].Moreover,VANETscanbeconsideredasdistributedsensors,wheresensorcollectsdifferentobservationsandreportsthemtolocalbase-stationsforexampleaverage speeds, potholes, temperature, pollution, etc [5]. VANETs canalso be used for entertainment services to the users by enabling filesharing, advertisements and voice communication with nearby vehicles[6]. The key component for developing applications in VANETs isinformationdisseminationtoagroupofaffected/interestedvehiclesoraroadsideinfrastructure.
[2, 9]. So far, there have been many research works concerning theefficientandseamlessinformationdisseminationinVANETs.Forinstance, in [1], the authors have developed a hybrid architecture thatcombinesvehicle-to-vehicle(V2V)communicationandvehicletoroadside sensor communication for enriching road safety informationwhichincludesbothaccidentpreventionandpostaccidentinvestigation. The roadside wireless sensor networks is used howeveronly for collecting environmental data and exchange them with thepassingvehicles,whichdoesnotfulfillthediverseapplicationrequirement of VANETs. Rayanchuet. al. have introduced a scalablearchitecture for vehicular traffic information dissemination based onpublish/subscribe model [10]. In that work, authors have proposed aconnected decentralized system for traffic information disseminationinsteadofcentralizedsystemtoenablescalabilityandoptimaldissemination. The architecture was developed considering the efficienttrafficinformationdisseminationandcannotbeusedforvaryingscenarios of VANETs applications. In [7, 8, 12], authors have proposedmiddleware platform that enables the application developers to publishnotifications to group of affected vehicles. The proposed middlewareenabledthedrivers/vehiclestoexpressinterestsaboutcertainnotifications and used information from the

satellite Navigation System(NS) for efficient dissemination of information. This middleware is toogenericwhichmakesapplicationdevelopmentcomplex.Forinstance,

Datadisseminationisthepropagationofinformationtoneighboring
nodes of the networks or to the set of target nodes located in a specificgeographical area. It can be used for extending the reach of safetyinformationandemergencywarningmessagesforVANETs,exchangingneighborhoodinformationqueriesaswellasrelayingdata
the authors provided primitives for defining information format ratherthan defining any common information format or topic (informationcontext) which resulted into application dependent information formatdesign which should be done by the application developer. Moreover,theymainlytargeteddisseminationofnotificationbydifferentpublishers for interested subscribers and hence considered time anddestination asakeyparameter forinformation.Thoughthe useofpublish/subscribeparadigmenhancemessagedisseminationperformance, subscription is not necessary for every applications inVANETs (e.g. road construction information, accident notification etc).Webelievethatsubscriptionofservicedependsonthetypeofinformation the service provides, in order to notify the users efficiently.To overcome these problems, we have defined a common informationformat considering varying VANETs application domains along withavailablecommunicationinfrastructures.Inthesameway,weareproposinginformationdisseminationarchitecturesfordevelopingdiverseapplicationsinVANETs.
In this paper we examined different scenarios of VANETs to define acommon information format that can be used for varying applications.Wehavealsoassumedthepublish/subscribeparadigmalongwithnavigationsystemfordisseminationoftheinformationtotheinterested/affected users. Our aim is to develop an architecture whichenables diverse application development using common informationformat and supports seamless and efficient information disseminationsin varying VANETs scenarios. To develop the generic architecture forVANETs applications following steps are pursued: 1) Analyze possiblescenariosofVANETsapplicationdevelopmentdomain2)Designcommoninformationformatfordiverseapplication3)Developarchitecture for data dissemination based on available communicationinfrastructurefromany nodeofVANETs.

1. VANETsapplicationdevelopmentscenarios

WesurveyforVANETsapplicationsandclassifythepossibleapplicationsenabledbyvehicularcommunicationsystems andcategorizedthemintothreetypesbasedoninformationtypeandpriority:PredefinedHigh,PredefinedLowandIncident.Understandably,themostcommonlyconsideredapplicationsarerelated to road safety and traffic management notification we namedthese applications as predefined high. For the accident notification andmanagementrelatedapplicationswenamedthemasincident.Thetravelerinformationsupportandvariouscomfortinformationarenamed as predefined low. Each of these three types of applications istiedwithtypeofinformationsincetobedisseminated,availableinfrastructure i.e. the type of communications which is necessary forinformation dissemination. The characteristics (whether it is known tothe authority ahead, priority etc) of the information to be disseminatedis important to analyze as it helps to determine whether subscription isnecessary for an application or not. Brief description of each type ofapplicationisasfollows:
PredefinedHigh:Theinformationinpredefinedhighcategoryisgeneratedbytheroadmanagementauthorityorsimilarinstitutes.For
instance, road construction notification, road safety information etc aregenerated or defined and disseminated to the vehicles as necessary.Subscriptions to these applications are not necessary as the informationmust be known by the users traveling through the affected areas. As aresult, this information will be received by all affected node (Vehicles)withoutsubscription.
PredefinedLow:Inthisapplicationcategory,theinformationisgenerated or supplied by the service providers (e.g. Govt. or privateorganizations), who usually provides different kind of services for theuser comfort such as parking information, lower fuel prices in an areaetc.Since,thisinformationisforusercomfortandnotinvolvedwiththe road safety, subscriptions based dissemination is appropriate. Thisimplies that, only the subscribed users of any application will receivecorrespondinginformation from the serviceproviders.
Incident:Applicationshandlingroadaccidentsandpostaccidenthazards falls under this category. The information in such application isof high priority in its nature and it is generated by the incidental vehicleitself.So,fromtheauthorityperspectivesuchinformationiscompletely unknown and hence the information needs to be carriedfrom incident place to the authority. Since, this application is related tothe road safety and hazard, it is required to be informed to the user whoareorwill be affectedby theincidentwithout subscription.

Table1:PossibleapplicationdevelopmentscenariosofVANETsbasedonapplicationtypes andavailableinfrastructure

Scenario no.	Applicationtype	Infrastructure	Supported
1	PredefinedHigh	AccessPoint	Yes
2	PredefinedHigh	V2V	Yes
3	Incident	AccessPoint	Yes
4	Incident	V2V	Yes
5	PredefinedLow	AccessPoint	Yes
6	PredefinedLow	V2V	No

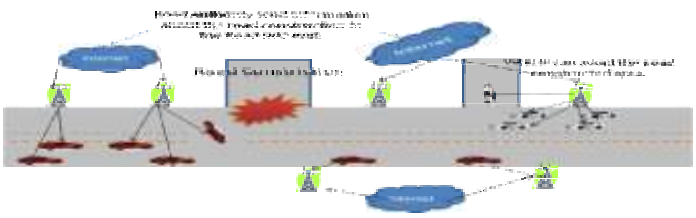
Nowbasedonthetypeofapplicationandavailableinfrastructureinvolvedintheinformationdissemination,diverseapplicationdevelopment scenarios of VANETs can be analyzed. Possible scenariosfor application development in VANETs based on above discussedcharacteristics are shown in Table 1. In our study, we did not considerthe V2V communication for “Predefined Low” application. This is dueto the mandatory subscription requirement for such application andhence the road side infrastructure is required to provide such services.Otherwise, for transferring information we need to use vehicles whichmay be not interested about such services and hence introducing ethicalissuesforusingunauthorizedresource.Supportedapplicationdevelopmentscenarios arediscussed below:

SCENARIO1:

Let’s consider a scenario of road constructions in area ‘A’ from 12thAugust to 15th August 2010 and the road authority wants to broadcastthis information to all vehicles that will use this route during that daterange (figure 1). Being informed about this predefined information theroad users can use different route to reach their destination and savetime. This will also reduce unnecessary traffic on the road on whichconstructionworksaregoingon,whichinturnreducetheriskof

accidents also. This scenario covers diverse applications involved fixedroad side infrastructure along with predefined information (e.g. notice)forthe vehiclesor users.

Now the question is how the information will be carried to the user. Ifthe area “A” is covered by any road side infrastructures (i.e. AccessPoint) (AP) then the information can easily broadcasted to all vehiclespassingthroughthesurroundedareawellaheadoftime.Inthisscenario the information is predefined high priority information and itcan be broadcasted from AP to all nodes (i.e. vehicles) in the targetedarea. The road authority is responsible for generating the informationalongwith selecting thearea of dissemination.



take such actions, the accident information is first transmitted to thecovering AP and AP takes necessary actions to handle the accidentalsituation. This scenario (figure 3) covers varied applications involvedfixed road side infrastructure along with incidental information (e.g.accident)forthevehicles orusers.

In this scenario, the information about the accident is unknown to theAP in advance and hence the information type is incidental. To handlepost accidental situation, at first the vehicles involved in the accidentgeneratesandsendstheinformationto the coveringAP.Sincetheaccident place is under coverage of an AP, the incident vehicle candirectly communicate with the AP using WiFi communication. Afterreceiving the incident information AP takes the initiative to handle postaccidentalsituationbyinformingcorrespondingauthorities.

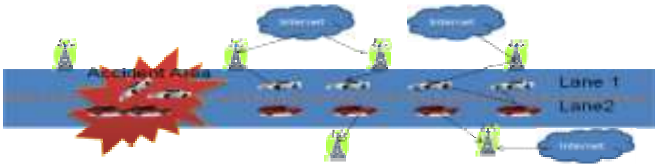


Fig 1: Dissemination of road side construction information to the vehicles oftargetedareasusingaccesspoint.

SCENARIO2:

Let'sconsiderthesimilarsituationasdescribedinscenario1exceptthattheroadconstructionarea'A' aswellasthetargetedareaofdissemination is no longer coveredbyroad sideinfrastructure(figure2).Thisimpliesthat,theinformationis"predefinedhigh"butitrequiresabsoluteV2Vcommunicationfortheinformationdissemination. This scenario covers any kind of applications involvedV2V communication or hybrid communication along with predefinedinformation(notice)forthe vehicles or users.

In such scenario, after generation of the information, it will be sent tothe nearest road side access point of the targeted dissemination area.Then the information will be broadcasted to the vehicles which aretravelingtowardsthetargeteddisseminationarea.Thevehiclewillbroadcast the information to all other vehicles within the designatedarea and the information will be kept available within the area for acertainamount of timetocontinuebroadcasting.

Fig 3: Dissemination of road accident information to the access point whichcoversthetargetedarea.

2.4SCENARIO4:

Let's consider an accident happened in a road segment which is notcoveredbyanyroadsideinfrastructurei.e.,AP.Now,totakeactionsfor handling the post accident situation, first the incident information isneed to be carried to nearest AP. Since, the place of accident is notcovered by any AP, V2V communication is required to forward theincident information to the nearest AP which will take further steps tohandle post accident hazards. This scenario (figure 4) covers differentapplicationsinvolvedV2Vcommunicationalongwithincidentalinformation(ex:accident)forthevehicles orusers.

In such scenario, after generation of the information, the informationwill be broadcasted to the vehicles which are traveling towards thenearestAP.ThevehiclewilldispatchtheinformationtotheAP,whenitwillreachunderthecoverageoftheAP.Similartothepreviousscenario, after receiving the incident information AP takes the initiativetohandlepost accidentalsituation.

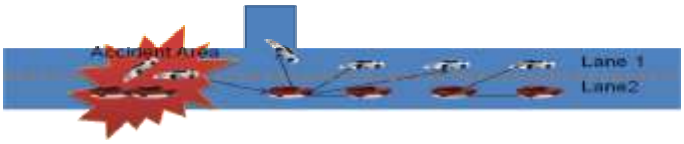


Fig 2: Dissemination of road side construction information to the vehicles oftargetedareasthroughV2Vcommunication.

2.3SCENARIO3:

Letusconsideranaccidenthappenedinaroadsegmentwhichisspotted under coverage of a road side infrastructure i.e., AP. Now, thepostaccidentsituationcanbeinvolvedcallingparamedics,policeand/orinformingroadauthoritiestotakenecessaryactions[11].To

Fig 4: Dissemination of road accident information to the access point nearest totheaccidentareathroughV2Vcommunication

2.5SCENARIO5:
The most frequent problems for the vehicles are finding parking spacesin an unknown area. The results for this will be waste of time and fuel.Asaresult,forVANETstechnologyitisaninterestingareaforapplication development through which any user can find out parkinginformationinanunfamiliararea.Thisactuallyrepresentsthescenario

in which many location aware service oriented application (e.g. fuelprice, advertisement, parking price etc) can be developed for VANETs.For these applications, the important thing is the subscription of theservice. This implies that, the vehicle will get information about aserviceonlywhentheysubscribetothat.Hence,theinformationpublished to the user in this scenario is known and service oriented assubscription is required. The subscriber can obtain the information onlyfromtheroadsideinfrastructurewhichmeansthatnoV2Vcommunication will be performed for providing such services. Thisscenario (figure 5) covers diverse subscription oriented applicationsinvolvedfixedroad side infrastructure.
In this scenario the road side infrastructure broadcasts the informationandonlythesubscribedvehicles/usersreceivetheinformation.Theuser should subscribe to the service through the subscription optionprovidedby thepublisher.

Fig 5: Dissemination of service oriented information from the access point to thevehicles/userswhohassubscribedtheservice.

2. Commoninformationformat
Analysis of different application development scenarios enables us toidentify the necessary context of the information, defined by differentproperties,foreachapplicationandintegratethemtodevelopthecommon information format for all applications. In case of receivingany information, the information should accurately describe the contextof the information so that the receiver can determine whether it isinterested in it or not. When any information is received at a node ofVANETs, the node has to determine whether it must accept, in case ofpredefined high and incident information, or it is interested in it or notin case of subscription based services or predefined low information.While transmitting, the information should also describe the context oftheinformationsothatthetransmittercandeterminewhetheritneedsto be transmitted, what is the correct location or time for transmissionetc.Incaseofspecificgeographicalareabasedinformationdissemination,onemajortaskistodefinethetargetarea.Differentlevel of common information format is shown in figure 6 and attributesofthecommon informationformatare discussedbelow:
Info ID: A unique ID of the information provided by the informationgenerator which can be used for tracing the source as well as discardingmultiplecopyofsingleinformationbythereceiver.
Text:Describethecontentsoftheinformation.
Type:Describethetypeoftheinformationi.e.predefinedhigh,predefinedlowor incident,whichisdefinedinthe previoussection.
Level of Dissemination: Determines number of times information willbe retransmitted. This can also be considered as number of hops. If thevalueisveryhighitmeans itwill befloodedwith in theareaofdisseminationfor the defineddurationof time.
Source: Describes about the generator of the information. It can beeithervehiclei.e.registrationnumberoraccesspointi.e.,serviceproviding id (ex: road authority, parking information service provideretc). It also includes the exact location of the information source, whichis especially important for tracing back the accidental vehicle in case ofincident information. The location isdefined based on latitude andlongitude,to preserve uniqueness.
Area of Dissemination: There can be several schemes for defining thearea of dissemination, here for simplicity we used the rectangular gridfor defining the area of interest based on the center (latitude, longitude),widthandheight.Thisislowlevelschemefordefiningthedissemination area which can also be used for higher level locationmapping (junction of road section, highway segment and city area)duringapplicationdevelopment.Similarhighlevellocationinformationcanalso beusedincase ofsource location.

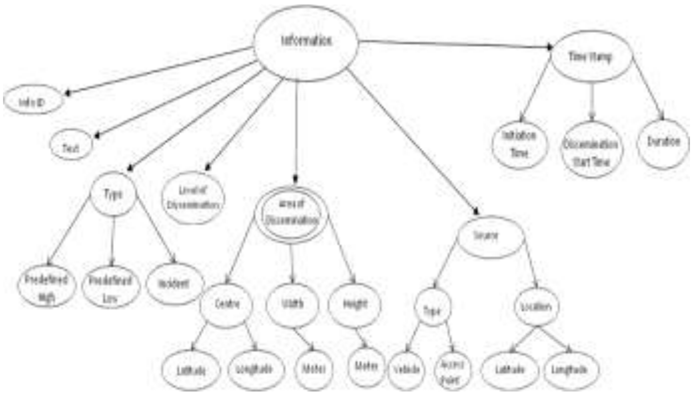


Fig6:Treeviewofattributesofcommoninformationformat.

TimeStamp:Ithasthreeparts:i)Initiationtime:ThisisrequiredwhenaV2Vcommunicationisrequiredandtheinformationisgeneratedinan access point. In such case this time indicates the time the accesspoint should start disseminating the information so that it reaches andbeingdisseminatedatthetargetdisseminationareaontime.ii)DisseminationStartTime:Itdescribestheexactdisseminationstarttime of any information. Date Time data format should be used fordefiningboththeinitiationanddisseminationstarttime.iii)Duration:Itdescribesthelengthoftimetheinformationshouldbedisseminatedinadissemination area.Unitusedfor durationisminute.

3. ProposedDistributedarchitectures

In this section we illustrate our framework. We have designed twoarchitectures: one for the vehicle itself and the other for the road sideinfrastructure. Two different architectures are required to consider allcommunication mechanism as like Vehicle to V2V to Infrastructure(V2I).Asdepictedinfigure7and8,botharchitecturesarecomposedby anumberofcomponentsthatinteractwitheachother.

Middlewarearchitectureforvehicle:

The middleware architecture for vehicle is shown in figure 7. Details ofthe each component of the distributed architecture for the vehicle aredescribedbelow:

Application: The application calls the Information Generator in ordertocreateInformation.Itinvokessubscribeandunsubscribemechanism

from the Subscription manager. The application is informed by theMessageFiltercomponent aboutthe receivedinformation.

SubscriptionManager:itwillkeepalltheinformationaboutthesubscribedserviceandhelptomatchthesubscriptioninformationrequiredby themessage filter'scomponents.

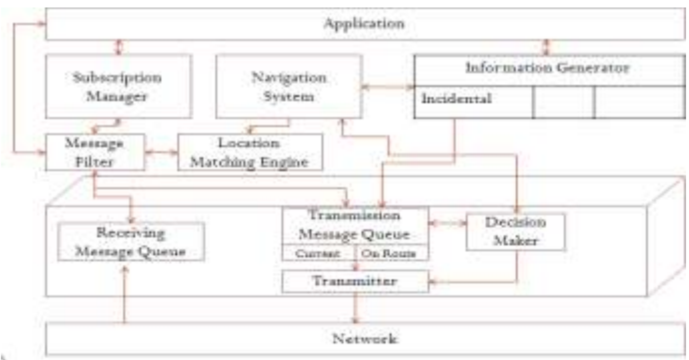


Fig7:Proposeddistributedmiddlewarearchitectureforvehicle.

Transmitting Message Queue: Stores all messages for transmission.The messages from Transmission Message Queue are removed by theDecision Maker component. Transfer of information from On RoutequeuetocurrentqueueisalsoperformedbyDecisionMakercomponent.It has two parts one is Current Queue:

is the messagewhich is currently transmitting and On Route Queue: it store messageforfuturetransmissionwhichismovedtoCurrentQueuebytheDecisionMakercomponent justbeforetransmission.

Message Filter: Checks the type of information and takes furtheraction. For example, send the information to the Transmission Queue iffurther broadcasting is required. It also displays the information to theuser.Processingofreceivedinformationdependsonthetypeofinformationas describedbelow:

PredefineHigh:

i) Checksthecurrent location withthehelpofLocation MatchingEngine.

ii) If the vehicle's current location is within the dissemination area thenit displays information to the user and sends the information to theCurrent queue of transmission message queue only in case of V2VcommunicationandLevelofDisseminationisnonzero,whichindicatesthatfurtherdissemination isrequired.

iii) If the dissemination area is on the way of the vehicle's route then itwill display information to the user and send the information to the Onroutequeueof Transmissionmessage queue.

iv) If the dissemination area does not match with the current location ornotonthevehicle'sroutethenitwill discardtheinformation.

PredefineLow:

FirstchecksthesubscriptionstatuswiththehelpofSubscriptionManager.ThenitsendsthemessagetotheCurrentqueueof Transmissionmessage queueforbroadcasting.

Incident:

- Incaseofnon-incidentalvehicle:

i) SendssourcelocationofinformationtotheLocationMatchingEnginetofindout thenearestAP.

ii) If the vehicle's current location is within the AP zone then it willsend the information to the Current queue of Transmission messagequeueto broadcasttothenearestAP.

iii) If the location of nearest AP is on the way of vehicle's route then itwillsendtheinformationtotheOnRoutequeueofTransmissionmessagequeue.

iv) IfnoAPislocatedontherouteofthevehiclethentheinformationis transferred to Current queue of Transmission message queue forinstanttransmissiontotheotherVehiclesonitswayforacertaintime.

- Incaseofincidental vehicle:

It will just generate the information and transfer it to the Current queueof Transmission message queue to broadcast randomly to the nearestAPorVehiclesfor acertaintime.

Location Matching Engine: It matches a location with the currentlocationandvehicleroutinginformationtodecidethe:i)currentlocation, ii) whether it is on the route of the location or iii) not on theroute of the location. It also provides the location information of theroadsideinfrastructureswiththehelpofnavigationsystem.Furthermore this matching engine is able to calculate distance betweentwolocations.

Navigation System: The navigation system holds the navigation orroute information of the vehicle. It also keeps the location informationofthe roadsideinfrastructure.

Information generator: This component generates the information ofan incident situation and forwards to the transmission message queuefor transmission.For setting the source (e.g. accident place) location ofthe information it takes the location information from the navigationsystem.

Decisionmaker: Accessesnavigationsystemtochecktheareaofinteresttoindicatetransmittertobroadcasttheinformationonthedesire location or remove the information from the Transmission queue.**Receiving Message Queue:** Temporary storage for received messagesfromNetworkLayer.Messagefilteraccessmessagefromthisqueueforfurther processing.

Transmitter: It transmits the information from the Current Queue tothenetworklayer.

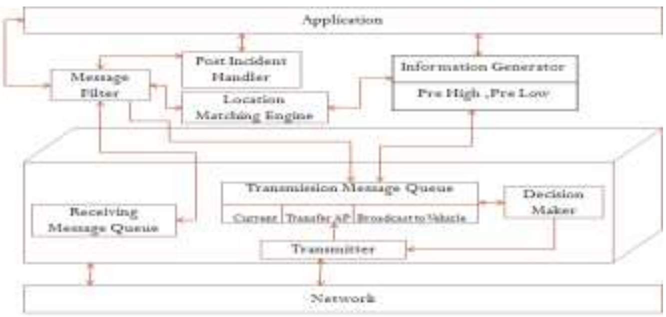


Fig8:Proposeddistributedmiddlewarearchitectureforroadsideinfrastructre.

Middlewarearchitectureforroadsideinfrastructure:
The middleware architecture for access point is shown in figure 8.Details of the each component of the distributed architecture for roadsideinfrastructurewhicharedifferentfrompreviousarchitectureare describedbelow:

MessageFilter: SimilartotheMessageFiltercomponentofarchitecture for vehicle, it also checks the type of information and takesfurtheraction,displaystheinformationtotheuser.Thoughtheprocessing of received information depends on the type of informationas described earlier, here the action steps are different and describedbelow:

<u>PredefineHigh:</u>

i) Checks either the target dissemination area is the within range of thisAPorit isthenearestAPwiththehelpofLocation MatchingEngine.

ii) If the target dissemination area is within the AP then it sends theinformationtotheCurrentqueueofTransmissionmessagequeue.

iii) Incontrast,ifthetargetdisseminationareaisnotwithintherangeoftheAPbutitisthenearestAPthentheinformationwillbetransferred to the Broadcast to Vehicle of Transmission message queue.Otherwise, it will simply forward message to another AP to reach thetargetdissemination area.

<u>PredefineLow:</u>

If the target dissemination area is within the range of the AP then themessagewillbetransferredtotheCurrentqueueofTransmissionmessagequeueforbroadcastingotherwiseitwilltransfertotheTransferAPqueueofTransmissionmessagequeue.

<u>Incident:</u>

First checks whether the AP is the first one to know about the incident.Ifso,theninform(callemergencynumbers,sendemailetc)corresponding authorities (e.g. paramedic, security, road authority etc)to takenecessarysteps to handlepost incident hazards and updatecentralincidentdatabase.Otherwisediscardmessage.

Location Matching Engine: It matches any location with the locationoftheAPanddecideswhetherthelocationiswithintherangeoftheAPoritisthenearestAPforthatlocationusingthelocationinformationofotherAPs.

Post Incident Handler: It invokes corresponding authorities to handlepostincidenthazardswhenevercalledbytheMessageFilter.

Decision maker: It checks the messages of Broadcast to Vehicle queueandcheckstheinitiationtimeattributesvalue.Themessageistransferred to the Current queue whenever the current time matches theinitiation time. For messages in the Transfer AP, it instantly sends themessage to the nearby APs using suitable routing techniques. It alsoindicates transmitter tobroadcasttheinformationfrom the Currentqueueorremovetheinformationfromthe Transmissionqueue.

Receiving Message Queue: Temporary storage for received messagesfromNetwork Layer.Message filter access message fromthis queueforfurther processing.

Transmitting Message Queue: Stores all messages for transmission.The messages from Transmission Message Queue are removed by thedecisionMakercomponent.Ithasthreeparts:i)Current:Storesmessages which are currently transmitting ii) Transfer to AP: Storesmessagestotransmittootherroadsideunits(AccessPoints)andiii) Broadcast to Vehicle: Stores messages which will be transmitted tovehiclesinnearfuture,i.e,waitingforfuturetransmission.

CONCLUSION

Inthispaper,wehavepresentedcommoninformationformatandoverview of initial design of distributed architectures for applicationdevelopment in VANET. We have considered all analyzed applicationdomains to design the common information format diverse applicationsof VANET. Though we have spent lot of time on analyzing differentapplicationdomainsofVANETusingdiversescenarios,ourmiddlewaredesignisstillinearlystages.Wehaveanalyzedthepossibleinteractionsbetweencomponentsofarchitectures,butthereare still interesting questions and challenges on how to improve thearchitecture.Infuture,weareplanningtoimplementandtesttheproposedarchitecturesusingsuitable simulator.

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