

Context-based BSM Aggregation for Broad-Scale Applications in Vehicular Networks

Khiredine Benaissa

Department of Computer Science
University of Medea
Medea, Algeria
benaissa.khiredine@univ-medea.dz

Salim Bitam

LESIA Laboratory
Department of Computer Science
University of Biskra, Algeria
s.bitam@univ-biskra.dz

Abdelhamid Mellouk

LISSI Laboratory
Department of Networks and Telecom
University Paris-Est de Crteil, France
mellouk@u-pec.fr

Abstract—In the U.S, the Basic Safety Message (BSM), commonly known as heartbeat message, has been proposed as the primary message set used by the connected vehicles' safety applications to constantly exchange data within the vehicular ad hoc networks (VANETs). BSM is communicated around 10 times per second through Dedicated Short-Range Communications (DSRC) to be exclusively used in the safety context. Once the BSM is used, it becomes obsolete and is destroyed. Nevertheless, albeit the BSM has been primarily developed to be used in the safety context, it has a capacious field of use. Other connected vehicle non-safety applications, like efficiency, environment, weather and mobility, may also use the data in the message. A wide range of BSM data elements are required by an important bunch of non-safety applications. Leastwise, core data elements of the BSM part one if cached, grouped and sent otherwise, they can solely and adequately provide the vehicle-based information needed for broad-scale applications. In this paper, we propose an Application-Level Flextime Aggregation (ALFA) scheme, allowing BSMs to be cached on-board the vehicle, intelligently aggregated according to different contexts and then sent in new message containing stored snapshots for every stretch of roadway. These new messages could be sent to vehicles and infrastructures, via Wi-Fi, digital cellular, or over a combination of all to provide broad-scale applications with needed information. The main novelty of our ALFA scheme is its contribution to change the way active safety transportation data (BSM) is treated, making it more valued, resulting in reliable and useful data source, and an efficient transportation network scaling to large areas. After a study case relevant to the vehicles mobility, obtained results showed that ALFA enhances the BSM' usefulness and provide mobility applications with useful input data.

Index Terms—BSM, Aggregation, VANETs, SAE J2735.

I. INTRODUCTION

Transportation systems are evolving toward intelligent transportation systems by applying information and communication technologies in the domain of transport, including infrastructure, vehicles and users. The embedding of new communication technologies within vehicles and transportation infrastructure is revolutionizing the way we travel. Through the enabling technologies, a bunch of embedded applications are able to collect and diffuse helpful information among vehicles and between vehicles and infrastructure in pursuance of assisting people to travel safely and comfortably [1].

In the U.S, the National Highway Traffic Safety Administration (NHTSA) aims at improving road safety by addressing the limitation of vehicle sensing technology to facilitate the

implementation of vehicle-based safety applications. Nowadays, in-vehicle Original Equipment Manufacturer (OEM) and aftermarket safety systems are all using DSRC to exchange data into what is known as a BSM over a wireless medium [2]. By real time exchanging of BSMs, safety applications are capable of detecting and identifying potential hazardous events and warn drivers before they experience them or automatically start vehicle control systems to respond to the impending events.

On the one hand, the BSM is currently exclusively used in the context of safety. Where, only safety applications can directly benefit from the received BSM. However, it can be argued that, safety, efficiency, mobility and other aspects cannot be considered as separated ensemble of characteristics. Evidently traffic accidents can engender traffic jams and can affect CO2 emission. For instance, from the perspective of proximate vehicles a message reporting a hazard can be observed as a safety message by safety applications. However, transport efficiency applications within distant vehicles may consider the same message as an input to estimate a new alternative route [3].

On the other hand, it is assumed that every vehicle has to send its BSM approximately 10 times per second to surrounding vehicles over DSRC band. Once the BSM is used, it becomes obsolete and is destroyed [4]. Albeit the BSM has been primarily developed to be used in the safety context, it has a wide range of use. The data in the message if cached, grouped and sent otherwise, may also be used by other non-safety applications [5], like efficiency, environment, weather and mobility. In this paper, we propose a new Application-Level Flextime Aggregation (ALFA) scheme in consideration of the global context of a transportation scenario, where, Intelligent Transportation System (ITS) are anticipated to significantly improve safety, decrease CO2 emissions, reduce road congestions and energy consumption [6]. The ALFA scheme caches BSMs on-board the vehicle and then aggregates them into new messages containing stored snapshots according to contexts for every stretch of roadway. These new messages could be sent to roadside DSRC units spaced along the roadway, sent via digital cellular, Wi-Fi, or through a combination of all to provide broad-scale applications with needed information. The main novelty of ALFA scheme is its contribution to change the way active safety

transportation data (BSM) is treated, making it more valued, resulting in reliable and useful data source, and an efficient transportation network scaling to large areas. The rest of the paper is structured as follows. Section 2 describes related work. section 3 introduces and describes the proposed ALFA scheme. Section 4 illustrates the evaluation of ALFA scheme through an example application using OMNeT++. Our conclusions are presented in section 5.

II. RELATED WORK

Nowadays, transportation systems confront critical situations owing to the growing mobility. overcrowding, traffic injuries, air pollution, etc., all require new ways to ameliorate the transportation system. Connected vehicle applications are anticipated to deal with those critical situations and help finding effective solutions for a safer, more efficient and sustainable future intelligent transportation systems (ITS) as well.

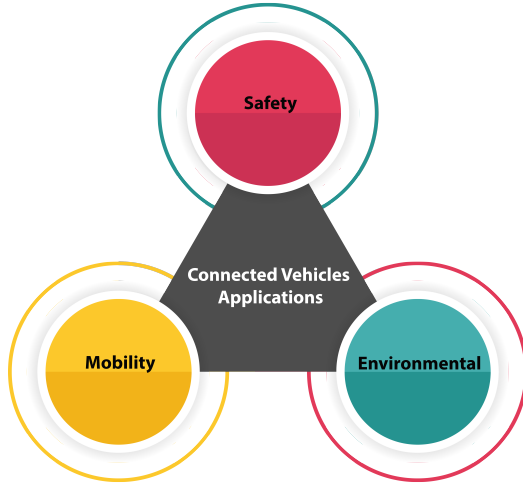


Fig. 1. Connected Vehicles applications.

A. Connected vehicles applications

VANET based applications permit the collection and the dissemination of utile information among vehicles and between vehicles and infrastructure to assist people travel safely and comfortably [7]. When referring to VANET applications purpose, it should be noted that they are grouped in two broad categories, safety and non-safety applications. Although, as is illustrated in figure 3, according to the U.S DOT connected vehicle program¹, applications are categorized into three main categories summarized in Table 1.

B. SAE J2735 DSRC message sets

In this SAE standard, a message set dictionary has been defined specifically to support interoperability among DSRC applications. The SAE J2735 groups an ensemble of message types, each message type is a generic structure and each

¹http://www.itga.org/wp-content/uploads/2015/12/CV-102-Participant-Workbook_Sept2015.pdf (last accessed April 10, 2018).

TABLE I
CONNECTED VEHICLES APPLICATIONS.

Category	Bundle	Number of application
Safety (13)	V2V	6
	V2I	7
Mobility (16)	MMITSS	5
	EnableATIS	
	INFLO	3
	R.E.S.C.U.M.E	3
	IDTO	3
	FRATIS	2
Environmental (25)	EcoSignal Operations	3
	EcoLanes	3
	Low Emissions Zones	3
	EcoTraveler Information	3
	EcoIntegrated Corridor Management	3
	Road Weather	3

message is a particular representation of a message type. The J2735 has identified and formatted each of the message types. Likewise, each message type has been defined as a collection of data structures known as data elements and data frames. A data element is the atomic data structure in the J2735 standard and is not further subdivided. A data frame is the next up level of data structure including one or more data elements or other data frames. The semantics and syntax of each data element and data frame has also been defined in the standard [3][4].

C. The Basic Safety Messages (BSM)

As explained above, SAE standard J2735 describes an application data message set. Among these, the BSM is considered as the most important message in the standard and it represents the here I am message as well. The BSM is constructed using data frames, which in turn are constructed using either other data frames or data elements. Accordingly, the BSM is split into two parts, the BSM Part I contains the core data elements, such as vehicle position, speed, heading, brake system status, and vehicle size. The BSM part I has priority and is transmitted more often. The BSM Part II contains a set of data elements that can vary by vehicle model. The content of Part II data depends on the triggering events. For example, when a vehicle activates ABS, a data element named ABS activated is set and the vehicles BSM transmissions include a Part II message indicating that its ABS is active. Consequently, Part II data is transmitted less frequently [4].

Data Element: DSRCmsg_ID The DSRC Message ID is a data element used with each message in the framework to define which type of message follows from the message set defined by this Standard [4].

Data Element: Temporary_ID The Temporary_ID, an element of the Basic Safety Message is not the same as a device MAC value, although when used as a means to uniquely identify a device, both have many common properties. Unlike the MAC, the Temporary_ID element might occasionally need

TABLE II
RELATIONSHIP BETWEEN DSRCmsg_ID, Temporary_ID AND MsgCount DATA ELEMENTS [4].

Msg ID	Msg Content	Details	MsgCount Value
Given DSRCmsg_ID	New	Not changed Temporary_ID since the previous message	the sender shall increment the previous value
Given DSRCmsg_ID	New	Changed Temporary_ID since the previous message	the sender may set the MsgCount element to any valid value in the range (including incrementing the previous value)
Given DSRCmsg_ID	Same	less than 10 seconds have elapsed since it sent the previous message with that DSRCmsg_ID	the sender will use the same MsgCount as sent in the previous message
Given DSRCmsg_ID	Same	at least 10 seconds have elapsed since it sent the previous message with that DSRCmsg_ID	the sender may set the MsgCount element to any valid value in the range; this includes the re-use of the previous value

to be changed for purposes of privacy. As mentioned in the J2735 standard, the Temporary_ID value should periodically be changed to a new random value separately from any other identifier value in the vehicle. Accordingly, any possible relationship with any other identifier is out of reach for J2735 standard. A vehicle should abstain from changing the temporary vehicle ID when the event indicators are set [4].

Data Element: MsgCount The MsgCount data element is used to provide a sequence number within a stream of messages with the same DSRCmsg_ID and from the same sender. A sender may initialize this element to any value in the range 0-127 when sending the first message with a given DSRCmsg_ID, or if the sender has changed identity (e.g. by changing its Temporary_ID) since sending the most recent message with that DSRCmsg_ID. In usage, a change in Temporary_ID data element value (which also changes the message contents in which it appears) implies that the MsgCount may also change value. Moreover, if a sending device sends more than one stream of messages from message types that utilize the MsgCount element, it shall maintain a separate MsgCount state for each message type so that the MsgCount value in a given message identifies its place in the stream of that message type. Table 2 above resumes the relationship between DSRCmsg_ID, Temporary_ID and MsgCount data elements [4].

D. VANET wireless access methods

Various wireless communication technologies are available in VANET. For vehicular safety communications, the task of outfitting vehicles with wireless communications appertains to car manufacturers, known in the automotive industry as original equipment manufacturers (OEMs). In contrast, for other communications, it is expected that OEMs rival with telecommunications companies utilizing cellular, Wi-Fi and WiMAX wireless technologies [3]. Typically, these technologies rely centralized infrastructure mode or ad hoc mode to coordinate the communications between nodes. Given the above wireless access possibilities, we can append (it is notable) that many research has explored aggregations possibilities of these wireless technologies (DSRC, Cellular, Wi-Fi, WiMAX) to provide rich and powerful nextgeneration communication network for connected vehicles [8].

E. VANET Data aggregation

Data aggregation is known as any process in which information is gathered and expressed in a summary form [9], for purposes. A common aggregation purpose is to get more information about particular groups based on specific variables. In VANET, several data aggregation approaches and mechanisms have been introduced. Authors of [15] suggested that instead of averaging information about road segments, only the most relevant single information items for a certain stretch of road are communicated to further away vehicles. Focusing on flexible decision metrics, a wholly structure-free data aggregation mechanism is described in [16]. Authors of [17] have introduced time aggregated graphs as a data model particularly for road networks and spatiotemporal networks. An in-network aggregation mechanism has been proposed in [18] that aim at improving communication efficiency by summarizing information exchanged between vehicles. With the analysis based on real traces, an approach called aTree has been introduced by [19] to address the delay-constrained data aggregation problem. In [20], data aggregation mechanism for real-time observation and efficient dissemination of any kind of traffic information in VANETs has been presented. In order to improve transmission efficiency and increase data throughput, authors in [21] have proposed an adaptive frame length aggregation scheme. Considering different data aggregation solutions presented above, we definitely notice that these solutions are limited and suffer from some weaknesses. In fact, they generally have considered the bandwidth consumption problem, and proposed related data structure [10][11].

III. APPLICATION-LEVEL FLEXTIME AGGREGATION (ALFA) SCHEME: OUR PROPOSAL

A. Problem specification

As we know, the SAE J2735 - Basic Safety Message is the primary message set proposed to send data among vehicles and between vehicles and the infrastructure over on-board dedicated short-range radio communication (DSRC) devices. Although the BSM is primarily developed to be used in the safety context, other connected vehicle non-safety applications, like efficiency, environment, weather and mobility, may also use the data in the messages. Indeed, the assessment of Data Elements in the Basic Safety Message to determine the extent, to which the

BSM can support the needs of AERIS² and DMA³ programs' applications [5][6], had shown that data in the BSM part 1 and 2 is also required for DMA applications. In addition, the BSM Part 1 satisfies the major part of several AERIS applications that compute eco-trajectories for vehicles. Although the BSM can serve a numerous non-safety applications, it matters little how much quantity of information in BSM is needed for these applications, but, instead, whether or not the BSM can be utilized as currently defined and broadcast. As well, the following features can be listed (presenting the actual situation).

Versatility: The BSM which is a credible and precious source of information, can never be utilized outside safety context (by non-safety applications) as currently defined and broadcast. Nevertheless, a wide range of BSM data elements are required by an important bunch of non-safety applications. Leastwise, the core data elements of the BSM part 1 can solely and adequately provide the vehicle-based information needed for several applications [5].

Periodicity: The BSM is tailored for low latency and broadcasted at approximately 10 times per second. However, non-safety applications do not require BSMs 10 times per second but far less frequently [4]. For instance, safety applications require near-instantaneous information while other applications operate with data rates from once per second to once every 30 seconds, as well as, for certain applications, 15 observations per segment (e.g., 1 mile) per time step (e.g., 15 min) should be sufficient for confidence in the application outputs⁴ [5][6].

Distance: As required by V2V safety applications, the BSM is planned for localized broadcast via DSRC range. Although, large number of non-safety applications require BSM data elements captured over a wide area [5][6].

Age: The BSM message includes only real-time snapshots but no on-vehicle storage of BSM data has been expected as well. Once the BSM is used, it becomes obsolete and is destroyed [4]. Otherwise, BSMs certainly can provide broad-scale applications with the necessary vehicle-based information if cached and aggregated [5].

Access: On the one hand, albeit the scope of the SAE J2735 Standard is focused on DSRC, this message set, and its data frames and data elements, have been designed, to the extent possible, to be of potential use for applications that may be deployed in conjunction with other wireless communications technologies as well [4]. On the other hand, complete roadway coverage using DSRC has never been envisioned as a feasible option [6]. Hence, the use of other wireless technologies like: Cellular, Wimax, Wi-Fi or the combination between them leads to long distance and high speed communications, especially in

consideration of divers (non-safety) connected vehicles applications.

B. Basic ALFA concept

To overcome this critical situation, we propose a new Application-Level Flextime Aggregation scheme (ALFA). The main idea of ALFA is that no BSM would be destroyed; all BSMs should be cached, aggregated, packaged differently and sent in diversified manners to widely support other applications' needs. As Illustrated in figure 2, a vehicle receives BSMs from remote vehicles and information from local sensor observations. Using the ALFA scheme, the data received in form of information is simultaneously delivered to safety applications and cached. The cached data is then periodically and intelligently aggregated according to different contexts, packed into new message and disseminated across lower-level to neighbor and far away vehicles.

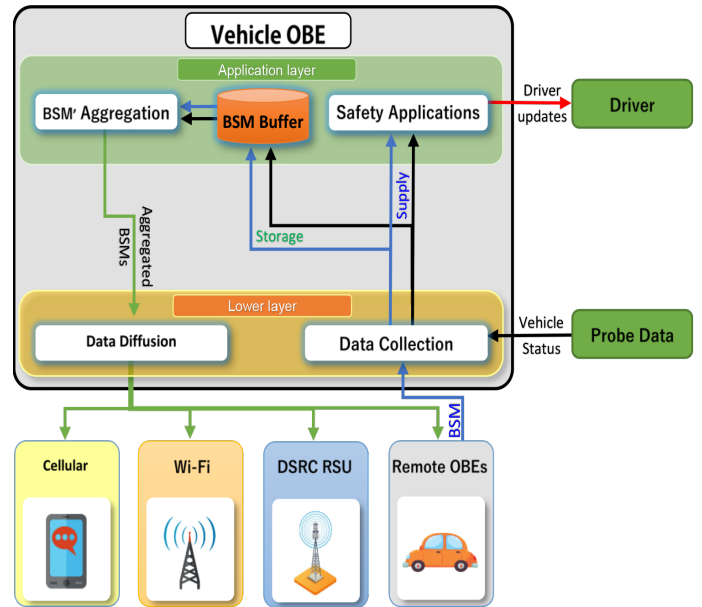


Fig. 2. The basic architectural concept of ALFA.

C. ALFA steps

In order to handle the ALFA scheme properly, each vehicle follows the detailed steps illustrated in figure 3. After initializing the waiting time, the vehicle starts receive new external BSMs. Once the BSM is received, the ALFA checks the TemporaryID and the MsgCount to determine if the received BSM possesses new content or not. If the content is new then the BSM is simultaneously sent to internal safety applications and cached, otherwise, the ALFA discards the received BSM and switches to receive another BSM. After the time runs out, or a safety application produces estimates an alert, the ALFA algorithm aggregates cached BSMs and creates new context-based messages to be broadcasted. Simultaneously, the algorithm initializes the waiting time as well as resets the BSM buffer to proceed the reception of new BSMs.

²Applications for the Environment: Real-Time Information Synthesis, see https://www.its.dot.gov/research_archives/aeris/index.htm (last accessed April 10, 2018).

³The U.S. Department of Transportation, Dynamic Mobility Applications, see https://www.its.dot.gov/research_archives/dma/index.htm (last accessed April 10, 2018).

⁴https://www.its.dot.gov/itspac/october2012/PDF/data_availability.pdf (last accessed April 10, 2018).

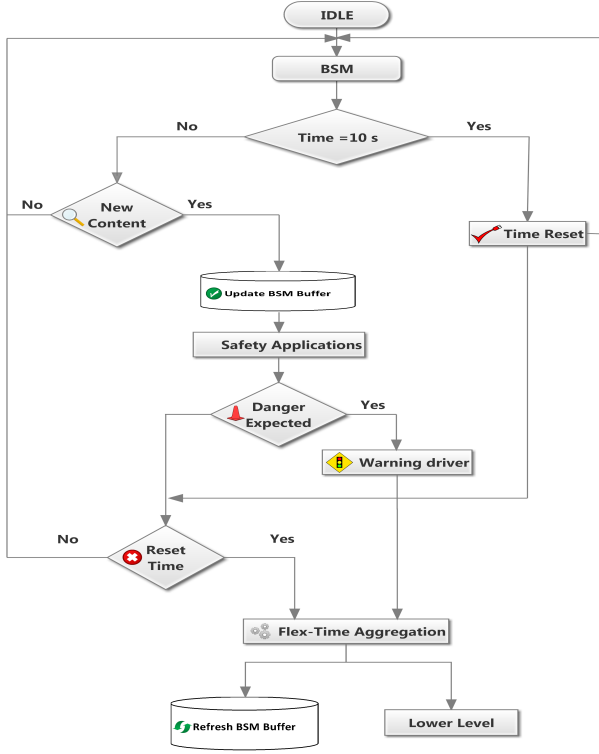


Fig. 3. Flowchart of the basic ALFA steps.

D. Mathematical representations of context-based approach

Mathematically, Data elements-contexts interactions can be characterized as two binary relations, $R_1(C, A)$, and $R_2(A, D)$ that describe an association between a set of contexts:

$$C = \{c_1, c_2, \dots, c_n\} \quad (1)$$

a set of applications:

$$A = \{a_1, a_2, \dots, a_m\} \quad (2)$$

and a set of data elements:

$$D = \{d_1, d_2, \dots, d_k\} \quad (3)$$

These relations are described by two ordered-pairs of elements (c_i, a_j) , (a_j, d_k) formed by the two Cartesian products of these two sets, $C \times A$ and $A \times D$ i.e.

$$(c_i, a_j) \in R_1(C, A) \subset C \times A \quad \forall c_i \in C \quad \forall a_j \in A \quad (4)$$

and

$$(a_j, d_l) \in R_2(A, D) \subset A \times D \quad \forall a_j \in A \quad \forall d_l \in D \quad (5)$$

For a given relation, an ordered-pairs represents a meaning related to the specificity of the relation. In this work, we are interested in whether a data element is used into a specific context. This is given by the characteristic functions $r_1(c_i, a_j) \in R_1$ and $r_2(a_j, d_k) \in R_2$, associated with the relations, which satisfy:

$$r_1(c_i, a_j) = \begin{cases} 1 & \text{if } a_j \subset c_i \\ 0 & \text{if } a_j \not\subset c_i \end{cases} \quad (6)$$

and

$$r_2(a_j, d_l) = \begin{cases} 1 & \text{if } d_j \subset a_j \\ 0 & \text{if } d_j \not\subset a_j \end{cases} \quad (7)$$

The elements (c_i, a_j) and (a_j, d_k) are generally collected into respectively $n \times m$ and $m \times k$ dimensional matrices.

$$r_1(c_i, a_j) = \begin{bmatrix} r_1(c_1, a_1) & \cdots & r_1(c_1, a_m) \\ \vdots & \ddots & \vdots \\ r_1(c_n, a_1) & \cdots & r_1(c_n, a_m) \end{bmatrix} \quad (8)$$

$$r_2(a_j, d_l) = \begin{bmatrix} r_2(a_1, d_1) & \cdots & r_2(a_1, d_k) \\ \vdots & \ddots & \vdots \\ r_2(a_m, d_1) & \cdots & r_2(a_m, d_k) \end{bmatrix} \quad (9)$$

It may also be desirable to represent the information in Equations, (6) and (7) as a network [12][13], since a considerable amount of information about the relationship between the applications data in VANET can be presented as networks. Specifically, when the entities that are being compared belong to different sets, for example contexts, applications and data elements, a bipartite network such as that given in Equations, (10) and (11) is commonly used:

$$N_1 = \langle C \cup A, E \rangle \quad (10)$$

$$N_2 = \langle A \cup D, E \rangle \quad (11)$$

These networks are comprised of sets of context and application nodes C and A , or sets of application and Data-element nodes A and D , that are non-overlapping, i.e. $(C \cap A) = \emptyset$ and $(A \cap D) = \emptyset$. Edges only link nodes between C and A or between A and D , there are no edges linking pairs of nodes within either C , A and D . Thus, the edge set can be defined as:

$$E_1 = \{e_1(c_i, a_j) \mid \text{if } (c_i, a_j) \text{ is an 'active' context-application pair}\} \quad (12)$$

$$E_2 = \{e_2(a_j, d_l) \mid \text{if } (a_j, d_l) \text{ is an 'active' application-element pair}\} \quad (13)$$

In networks, pairs of nodes directly linked by edges are said to be adjacent and constitute the elements of the $n \times m$ and $m \times k$ dimensional adjacency matrices:

$$A_1 = \begin{bmatrix} e_1(c_1, a_1) & \cdots & e_1(c_1, a_m) \\ \vdots & \ddots & \vdots \\ e_1(c_n, a_1) & \cdots & e_1(c_n, a_m) \end{bmatrix} \quad (14)$$

$$A_2 = \begin{bmatrix} e_2(a_1, d_1) & \cdots & e_2(a_1, d_k) \\ \vdots & \ddots & \vdots \\ e_2(a_m, d_1) & \cdots & e_2(a_m, d_k) \end{bmatrix} \quad (15)$$

It is not difficult to see the following properties:

An adjacency matrix is symmetric, that is for all i, j , $A[i, j] = A[j, i]$. This property reflects the fact that an edge

is represented as an unordered pair of nodes $e_1 = \langle c_i, a_j \rangle = \langle a_j, c_i \rangle$.

The sum of values in row_i is equal to the degree of $node_i$, that is, $\delta(c_i) = \sum_{j=1}^n A[i, j]$.

The following illustrative example shows the 3×7 dimensional context-application interaction matrix A_1 and the 7×8 dimensional application-data element interaction matrix A_2 . Figure 4, shows the related bipartite network graph as well.

$$A_1 = \begin{bmatrix} 0 & 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 & 1 \end{bmatrix}$$

and

$$A_2 = \begin{bmatrix} 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 \end{bmatrix}$$

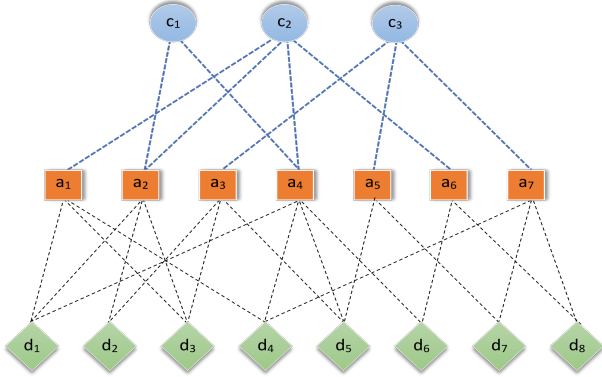


Fig. 4. Simple example of a bipartite context-application and a bipartite application-data_element networks made up of three contexts, seven applications and eight data_elements.

E. ALFA tasks

Inside a vehicle, the ALFA scheme can be sufficiently described by five tasks illustrated in figure 5.

1. Caching: In the application layer level, the ALFA scheme periodically acquires BSMs and in-vehicle sensed data from physical layer and caches them locally.

2. Filtering: For an intelligent and flexible aggregation, such as to avoid the overlapping of aggregates for the same area, cached BSMs are then filtered according to certain data elements like MsgCount, TemporaryID, DSecond, Latitude, Longitude, Speed, Heading, and VehicleSize.

3. Selection: Using the context-based adjacency matrix and cached BSMs, the ALFA scheme selects qualifying data elements and data frame for aggregation.

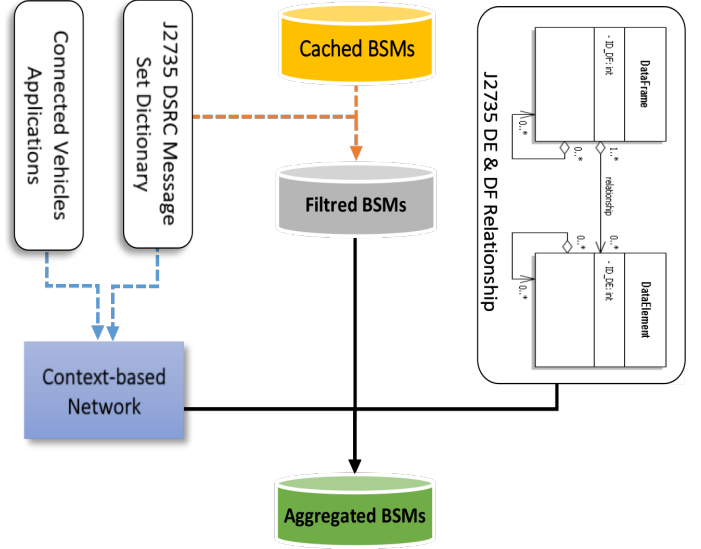


Fig. 5. ALFA scheme tasks.

4. Aggregation: Subsequently, to maintain scalability, qualified DE and DF are aggregated in terms of spatio-temporal, according to multiple criteria (We simply can aggregate the number of vehicles that have same size and aggregate the speeds within different ranges and diversified time intervals such as shown in figure 7) while respecting the relationship between DE and DF described in J2735. For instance, Figure 6 shows the Data Frame: DF_TransmissionAndSpeed which expresses the speed of the vehicle and the state of the transmission. The transmission state of 'reverse' can be used as a sign value for the speed element when needed.

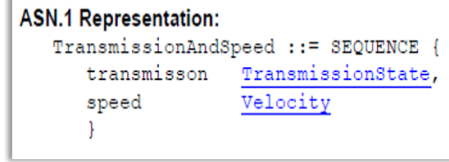


Fig. 6. Data Frame & Data Element relationship example.

5. Composition: A new Message Type is then constructed within the MSG Message Frame to hold aggregated data frames and elements. The new message type will have a new ID picked from the unreserved DSRCmsgID values.

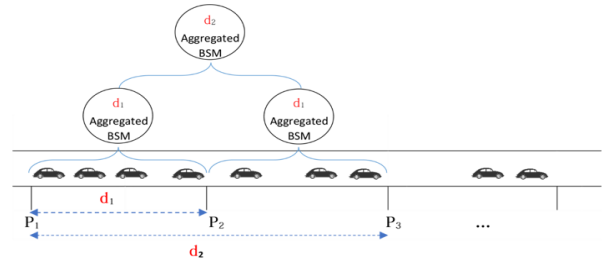


Fig. 7. BSM aggregation according to distance.

TABLE III
PREVIOUS DATA AGGREGATION APPROACHES VS THE ALFA SCHEME.

Previous approaches	ALFA scheme
Customized: Based on personal data structure. They are incapable to exchange data with other approaches and protocols	Standard; Based on standard data structure J2735 DSRC Message Set Dictionary. Data can be used and reused
Lower-level data aggregation	Application-level data aggregation
Lower-level number of forwarders elimination	Application-level data redundancy elimination
Special communication platforms	Combined communication platforms
The J2735 standard's Assumptions	ALFA scheme
BSM exclusively used in the safety context	Extend the BSM use to other contexts
Used BSMs are considered obsolete and are destroyed	Used BSMs are cached and aggregated

IV. EXEMPLE APPLICATION

The purpose of the exemple application is to deploy the ALFA scheme into the mobility context to demonstrate its functionality and performance using a virtual traffic environment based on real world applications needs.

A. Objectives

The first objective is to demonstrate basic functionality of ALFA, including its ability to:

Check the captured BSM content according to TemporaryID and MsgCount data elements and decide whether the BSM will be cached.

Filter cached BSMs according to: Position and Motions data frames, and VehicleSize data element.

Select qualified data elements for aggregation using the context-based adjacency matrix.

Periodically aggregate speed in correlation with location and vehicles number.

The second objective is to disseminate aggregation results using both DSRC and LTE communication technologies.

The third objective is to demonstrate that the aggregated BSMs would help far away vehicles to change their direction after a traffic accident.

B. Selected Applications

To illustrate how ALFA scheme can efficiently aggregate BSMs, we consider a construction of new message type that contains aggregated Data Frames and Elements for the Intelligent Network Flow Optimization (INFLO) application bundle within the DMA Program announced by the US DOT. As illustrated in Table1 above, The DMA Program initiated the development of 17 mobility applications, grouped into six bundles. The main purpose of the INFLO bundle is network flow optimization whether on freeways or arterials. To achieve that, motorists are continually informed of existing and impending queues and bottlenecks, provided by target speeds according to

TABLE IV
BSM DATA ELEMENTS USED BY INFLO APPLICATIONS.

BSM Part1	BSM Part2
Position (local 3D):	Road coefficient of friction
-Latitude	Wiper status
-Longitude	Wipers changedAmbient air Temperature
-Elevation	Traction Control System active over 100 msec
-Positional accuracy	Antilock Brake System active over 100 msec
Motion:	Throttle position (percent)
-Transmission state	Date/time of obstacle detection
-Speed	Azimuth to obstacle on road
-Heading	Distance to obstacle on road
-Steering wheel angle	Confidence-position
-Acceleration Set (4-way)	Confidence-speed/heading/throttle
Brake System status	Confidence-time
Vehicle size	Trailer weight, Cargo weight
	Recent or current hard breaking
	Level of brake application
	Vehicle data,Hazard lights activ

location and lane and have the capability to form ad hoc vehicle platoons of uniform speed.

BSM Data Elements: The set of data elements used by INFLO bundle have been selected based on the preliminary assessment results conducted in [6]. Except the most widely used data elements that are shown in Table 4, we only have considered BSM Part1 data elements for our demonstration. That is, our matrix will contain the INFLO buundle applications and BSM Part 1 Data Elements. **Parameter settings and evaluated metrics:** Our simulation is performed on a road surface of 2500×2500 m where each road segment contains two bidirectional lanes. Network simulation is performed by OMNeT++ while road traffic simulation is performed by Veins framework based on SUMO. Moreover, Integrating Veins into SimuLTE allows us to simulate cellular communications in vehicular networks. For each scenario, involved vehicles in BSMs exchange are 300, the maximum speed is limited to 90 km/s and the itinerary is haphazardly selected. The DSRC-V2V communications coverage is set at 300m while the LTE-V2V coverage is set at 5000m. For each scenario, we propose we propose a random accidents occurrence throughout the simulation duration. Furthermore, we consider the two types of speeds aggregation defined in [14] as:

1- Time Mean Speed (TMS):

$$S_{TMS} = \frac{\sum_{i=1}^n S_i}{n}$$

2- Space Mean Speed (SMS):

$$S_{SMS} = \frac{1}{\frac{1}{n} \sum_{i=1}^n t_i}$$

Eventually, table 5 shows the simulation parameters that are used to represent vehicles and driving behavior in next scenarios.

TABLE V
SIMULATION PARAMETERS.

Parameter	Value
Simulation Grid (X,Y)	2500m * 2500m
Vehicles densities	10 - 300
Vehicular Speed	10, 30, 50, 70, 90 km/h
Number of lanes	2
Vehicular traffic (packet size)	250 bytes
Simulation Time	300s
DSRC	
Transmission	300 metres
Packet Length	500 bytes
Data Rate	6 Mbps
Frequency	5.8 GHz
Channel bandwidth	10 Hz
LTE	
Transmission Range	5000 metres
Packet Length	7,500 bytes
Data Rate	78 Mbps
Frequency	DL-2,110 MHz UL-1,710 MHz
Channel bandwidth	10 Hz

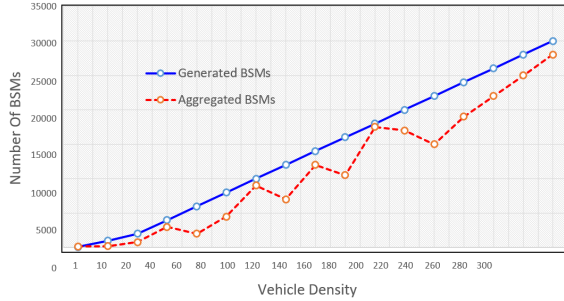


Fig. 8. Cached & Aggregated BSMs according to ALFA scheme.

C. Simulation results

The number of cached and aggregated BSMs is a significant metric especially in high density. This number should remain increasing as the number of vehicles in the network increases.

By equipping vehicles with the LTE technology along with DSRC, the coverage radius will considerably be increased and that would allowing a large number of messages to be broadcast over a long distance.

Figure 9 shows that ALFA scheme is outperforming the ordinary situation where all BSMs are deleted after local broadcast. Thus, in term of coverage, aggregated BSM are broad-scale disseminated over LTE which help distant vehicles to have useful traffic information on faraway area.

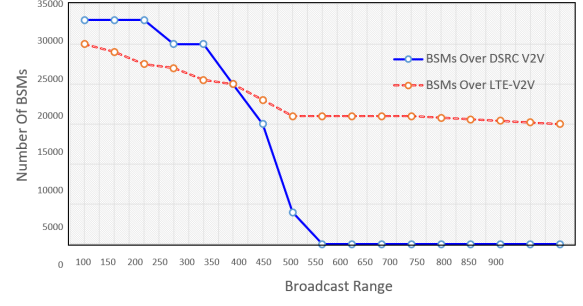


Fig. 9. V2V BSMs Broadcasting Over DSRC & LTE.

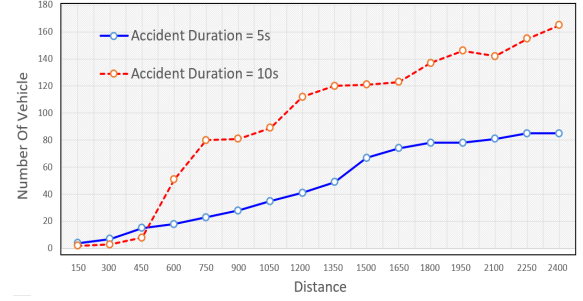


Fig. 10. Number of vehicles that changed road after the accident.

In figure 10, albeit, nearby vehicles were fortunate to instantly capture information about the short-time accident, it is most significant that several distant vehicles have better profit from the long-lived accident alert. as well as, the efficiency of ALFA is demonstrated the fact that distant vehicles have changed destination after receiving aggregated BSMs.

V. CONSLUCION

In this paper, we proposed a novel and efficient ALFA scheme, which aggregates BSMs to be used out of safety context. The novelty of ALFA scheme is its help to change the way active safety transportation data (BSM) is treated, making it more reliable and useful data source for other connected vehicle non-safety applications such as mobility, weather, and environment. The main contribution of ALFA was to intelligently aggregate BSMs according to different contexts and provide distant vehicles by useful information about broad traffic situation, which result in an efficient transportation network scaling to large area. In fact, with DSRC and BSM, the Connected Vehicle holds the promise of saving lives and reducing property loss. However, with Combined wireless access and ALFA scheme the Connected Vehicle will hold further promises of improving transportation efficiency, improving the environment and opening a new frontier for innovation. In our future work, we aim at improving the dissemination decision according to aggregation utility (AU) and that would definitely decrease bandwidth consumption. We also aim at using data base tool for long storing BSMs which help us extracting knowledge about the transportation system. for instance, about drivers behavior and general traffic conditions.

REFERENCES

- [1] M. Alam, J. Ferreira, "Intelligent Transportation Systems: Dependable Vehicular Communications for Improved Road Safety," Volume 52 of Studies in Systems, Decision and Control. Springer, January 2016.
- [2] K. Benaissa, S. Bitam, A. Mellouk, "Efficient Messages Broadcasting within Vehicular Safety Applications" IEEE 28th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC), October 2017.
- [3] H. Hartenstein, K.P. Laberteaux, "VANET: Vehicular Applications and Inter-Networking Technologies," 2010, ISBN 978-0-470-74056-9.
- [4] SAE international, "Dedicated Short Range Communications (DSRC) Message Set Dictionary," Technical report, Standard J2735, March 2016.
- [5] U.S DOT and NHTSA, "Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application," Technical report, August 2014.
- [6] U.S DOT and FHWA, "Vehicle Information Exchange Needs for Mobility Applications," Technical report, February 2012
- [7] M. Alam, J. Ferreira, "Intelligent Transportation Systems: Dependable Vehicular Communications for Improved Road Safety," Volume 52 of Studies in Systems, Decision and Control. Springer, January 2016.
- [8] K.C. Dey, A. Rayamajhi, M. Chowdhury, P. Bhavsar, J. Martin, "Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication in a heterogeneous wireless network Performance evaluation, ScienceDirect journal. Transportation Research Part C, March 2015.
- [9] Atlantic Publishers and Distributors Ltd., "Encyclopedia Of Information Technology," ISBN: 81-269-0752-5. New Delhi : Atlantic, 2007
- [10] S. Dietzel, J. Petit, F. Kargl, B. Scheuermann, "In-Network Aggregation for Vehicular Ad Hoc Networks." IEEE COMMUNICATION SURVEYS & TUTORIALS, VOL. 16, NO. 4, 2014.
- [11] H.R. Dhasian, P. Balasubramanian, "Survey of data aggregation techniques using soft computing in wireless sensor networks." IET Information Security journal. December 2012.
- [12] M. Newman, "Networks. An Introduction," Oxford University Press, Oxford, UK. 2010.
- [13] M. Van Steen "Graph Theory and Complex Networks. An Introduction," M van Steen Publisher; 2010.
- [14] S. Olariu, M.C. Weigle, "Vehicular Networks From Theory to Practice," Chapman and Hall/CRC Press, NewYork. March, 2009.
- [15] M. Van Eenennaam, G. Heijenk, Providing over-the-horizon awareness to driver support systems, IEEE workshop on V2V communications, 2008.
- [16] S. Dietzel, F. Kargl, G. Heijenk, F. Schaub, On the potential of generic modeling for VANET data aggregation protocols, IEEE vehicular networking conf., 2010.
- [17] B. George, S. Shekhar, Time-aggregated graphs for modeling spatio-temporal networks, Journal on Data Semantics, Springer Vol. 5383, 2008.
- [18] S. Dietzel, J. Petit, F. Kargl, B. Scheuermann, In-Network Aggregation for VANETs, IEEE communication surveys & tutorials, 2014.
- [19] Y. Zhu, Q. Zhao, Q. Zhang, Delay-Constrained Data Aggregation in VANETs, IEEE transactions on vehicular technology. 2014.
- [20] M. Milojevic, V. Rakocovic, Location-Aware Data Aggregation for Efficient Message Dissemination in VANETs, IEEE transaction on Vehicular Tec. 2015.
- [21] X. Zhou, A. Boukerche, An Adaptive Frame Length Aggregation Scheme for Vehicular Networks, IEEE transaction on Vehicular Tec. 2016.