Cohort-Based Construct for Vehicular Cyber-Physical Systems

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***Abstract*—Ensuring human life safety is inexorably the most critical objective of Intelligent Transportation System (ITS), which makes Intelligent Vehicular Network (IVN) the cornerstone of such system. Hence, in order to overcome network Quality of Service (QoS) degradation issues, several networking models for IVN have been proposed in the literature, namely cluster-based construction, cloud-based construction and platoon-based construction. Nevertheless, such constructions present several limitations, in terms of timeliness, connectivity and reliability, especially in critical environments. Therefore, we propose in this paper the design of a distributed construction based on "cohorts" and Neighbor-to-Neighbor (N2N) Communication, and we present the required cohort-managements distributed algorithms that ensure optimal IVN cohort-structuring and efficiency.**

Keywords–Cohort; Intelligent Vehicular Network; Cyber-Physical System; Safety.

I. INTRODUCTION

Saving road user's life is still the most imminent question of transportation systems since the automobile invention. Tightly associated with the automobile revolution and the population grown up, the road traffic condition turns into a critical social issue. The American National Highway Traffic Safety Administration (NHTSA) announces that 37 461 accidents related fatalities and 4.6 million injuries are recorded in 2016, and unfortunately this statistic continued to increase. In addition to, and according to European Transport Safety Council (ETSC) and NHTSA reports, more than 90% of road crashes are caused by human errors [1][2]. That is why, developing an Intelligent Transportation System (ITS) is considered as the main solution to achieve the goal of improving road traffic safety [3]. Thus, during the last decade, the road traffic safety challenge has attracted an interesting consideration from both academia and industry. Consequently, significant amount of resources are investigated around the world to develop safe and reliable ITS.

Initially, researches consider the paradigm of Autonomous Driving as a keystone for road safety and traffic efficiency, where an autonomous vehicle [2][5] is equipped with several computing, planning and sensing technologies providing different safety features, with the ability to discharge the human partially or totally from the driving task. However, autonomous vehicles are seen as isolated entities and cannot cooperate with their surrounding (vehicles or road equipment's). Thereby, a deaf autonomy cannot respond to the ITS' goal, which explains the need for autonomous vehicles cooperation mechanisms. Thus, tremendous attention was conferred to Collaborative Autonomous Driving which is mainly based on inter-vehicular communication, as described in [6].

Communicating vehicles are gathered into an unlimited-size self-organized network, characterized by dynamic topology, where inter-vehicular communication is based on broadcasting mode. Let us highlight the drawbacks behind this definition. Firstly, dynamic topology, caused by nodes' high mobility, is causing a grievous problem of dis-connectivity. Secondly, the broadcasting communication mode is suffering from the absence of feedback about the sent message reception/delivery, beside its ability to provoke network overflow, making a serious problem of transmission reliability. In addition, existing standards proposed in the literature to serve the vehicular environment are unable to guarantee bounded latency for safety-critical messages, resulting in a problem of timeliness.

Motivated by the necessity to surmount those limitations and by the evolution of distributed algorithms, we propose to structure the vehicular network into size-bounded vehicular string, so-called cohort, and we present the required cohort-managements distributed algorithms that ensure optimal vehicular network cohort-structuring and efficiency.

The remainder of this paper is organized as follows: in Section II, we briefly review the state of the art, by focusing on IVN and community converging towards such concept. We propose in Section III a cohort-based construct for Vehicular Cyber Physical System (VCPS) that we believe is more suitable for Safety-critical data dissemination. We propose in Section IV cohort management distributed algorithms. We conclude the paper in Section V.

II. STATE OF THE ART

Automotive industry has targeted to embed computerization into the vehicle driving task [7]. New vehicle models are integrating new features, impacting essentially the road traffic safety. The development is going further over time, and several manufactures around the world, like BMW, Tesla, Audi, Mobile Eye and Google, are in the race of Autonomous Driving System (ADS) development.

Autonomous driving system, also known as self-driving system, is based on on-board perception and sensing technologies, like radar, lidar, ultrasonic, optical sensors and camera. Such sensors are used to collect information from their environment. The collected data are gathered to create an accurate representation of the vehicle nearby surrounding. In addition, this data is also interpreted and analyzed, by an on-board

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processing unit, to help vehicle moving and reacting to safety-critical situations that might occur. Nevertheless, this solution has several limitations, which can be summed up in two points.

- Perception technologies performances can be lost due to equipment failure, obstacles and weather conditions. As example we can mention that radar sensors sight is limited by obstacles, optical and lidar sensors are influenced by bad weather conditions, e.g., lidar sensors cannot see when it rains.
- Being autonomous means acting according to its own system rules independently of external intervention from communication with other vehicles or infrastructures. This property turns it a passive and isolated entity, which can be a dangerous source in case of perception technologies lose.

Consequently, in order to overcome perception technologies limitations, system diversity and redundancies are required, similarly, to strategies used in most advanced fighter planes and deep-space satellites. Deploying a reliable vehicular communication strategy is a key redundant solution to support and defend the autonomy capacities. This principle explains the need for an intelligent vehicular network.

IVN is a vehicular self-organized network, generally providing the so-called vehicle-to-everything (V2X) communication, which can be vehicle-to-vehicle (V2V) communication, vehicle-to-infrastructure (V2I) communication, vehicle-to-pedestrian (V2P) communication, vehicle-to-bicycle (V2B) communication and vehicle-to-drone (V2D) communication. The most known and studied form of IVN in the literature, is Vehicular Ad hoc Network (VANET) [8][9][10]. Hereafter, we focus only on inter-vehicular communication V2V.

Safe transportation system reposes on real-time safety-critical (SC) inter-vehicular communication (IV) [11]. Thus, SC-IV communication algorithms and protocols are needed to coordinate IVN. IEEE 802.11p [12][13] is considered as the first standard designed for V2V and V2I communications. But unfortunately, this standard presents evident drawbacks essentially related to reliability issues, unbounded latency, security, unfairness of channel dedication. These limitations make, IEEE 802.11p standard, not suitable for real-time safety-critical applications. Moreover, the deployment of IEEE 802.11p standard requires huge investment in the network infrastructure, on-road units [9]. Then, motivated by the global deployment and commercialization of Long Term Evolution (LTE), authors in [9] propose an integrated solution for vehicular communication, both V2V and V2I, so called LTE-V, based on the time division LTE 4G technology. This proposition is expected to provide two communication modes: LTE-V-direct enabling short range direct and decentralized V2V communication, to support road safety applications requirements low latency and high reliability, and LTE-V-cell enabling centralized V2I communication. In addition, the solution provides high mobility support, optimized coverage and better resources allocation. In addition, direct Device-to-Device (D2D) based LTE V2V communication is proposed to guarantee inter-vehicular communication requirement in terms of latency and reliability [14][15][16].

All of these solutions are based on dynamic mesh topology, where nodes are characterized with a high mobility. Mobility, dynamic topology and unlimited density present serious impediments in front of reliability, connectivity and bounded latency guarantee. To alleviate as much as possible vehicular environment complexity, we propose to divide the set of vehicles in the roads into fully-distributed and bounded-size cyber-physical construct based-on directional communication, named cohort by G. Le Lann, [11][17]. Details about cohort are given in the following section.

III. Proposed Model/Solution

Breaking down the network into a fully-distributed, linear and size-bounded segment of consecutive vehicles is mainly inspired by the notion of platoons, which initially appeared around 1974. Due to the lack of space we cannot detail platoons characteristics and limitations, so, we recommend this work for more information [18].

A. *Cohort Introduction and Specification*

A cohort is a size-bounded ad hoc string of consecutive vehicles circulating on the same lane. Contrary to platoon, cohort is a fully-distributed cyber-physical construct based on perception technologies and directional Neighbor-to-Neighbor (N2N) communication. According to [11] cohort's concept is used to add some structuring to IVN and to achieve the road traffic safety. Consequently, the cohort construct is advanced, on one hand, to reduce the number of vehicle involved in rear-end braking crashes, and on the other hand, to alleviate interference and collision problems. The safety goals can be ensured by reducing, dramatically, incident and injury rates. Thus, safe longitudinal inter-vehicular spacing, as well as reducing velocities in the course of risk prone maneuvers are needed. The most important cohort characteristics are depicted on Figure 1.

A cohort Γ is a set of $n \leq n^{\bullet}$ (n is current cohort size and $n^{\bullet}$ is the max cohort size) contiguous vehicles, where the first member is called the cohort head and the last one is named the cohort tail [17][18]. Every cohort's member X is assigned a rank noted r_x, where, $1 \leq r_x \leq n^{\bullet}$. The cohort head is assigned the rank 1 and the cohort tail is assigned the rank n. A safe longitudinal spacing should be respected between the same cohort members and between cohorts circulating on the same lane. The inter-members gap (resp. the inter-cohort gap), so-called s_{xy} (resp. $S_{H/T}$), is bounded as follows $s^{\circ} \leq s_{xy} \leq s^{\bullet}$, (resp. $S^{\circ} \leq S_{H/T} \leq S^{\bullet}$) and tightly depends on the network density. Every isolated vehicle is considered as an isolated cohort where n =1.

Vehicles can freely leave their cohorts, by simple deceleration/acceleration or after a changing lane decision. However, after leaving its cohort, the vehicle X must join another

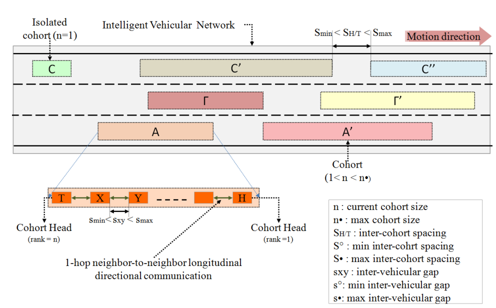

Figure 1. Cohort Specification.

cohort or creates its own one. Whatever, the decision is, joining an existing cohort or creating a new one, it cannot be carrying out arbitrarily. Actually, joining an existing cohort depends on two main factors, the cohort size, which cannot exceed the maximum value $n^{\bullet}$, and the available spacing to be inserted into, which must respect the constraint of safe inter-vehicle/cohort spacing.

Therefore, cohort management distributed algorithms are mandatory in such situation, to indicate the vehicle behavior. For the lack of space, we highlight, in this work, specifically, how a vehicle X must react after a lane changing maneuver (resp. a highway's first lane entrance). Several use cases are described hereafter, and different algorithms are proposed to show how these situations will be overcome.

B. System Model

All the use cases described afterwards, are supposed taking place on the highway. Then, we assume that the entire IVN on the highway is broken down into many cohorts of variable size. Each cohort is formed, as described above, by a bounded number of nodes moving in the same direction at a similar velocity. Cohort's members' cooperation is ensured by directional N2N communication. This communication paradigm is out of the scope of this paper, and for more details about N2N communication, we can refer to [17][19][20][21][22]. Periodic control messages exchange, equivalent of beaconing service in VANET and platoon, is essential for cohort management and local member data update.

In this paper, we focus on the lane changing maneuver. Accordingly, different use cases resulting from the lane changing maneuver are studied hereafter. Every maneuver, taking place on the road, is divided into cyber and physical phases. Our researches are concerned with the cyber ones.

Thus, cyber procedures are necessary to perform a safe and successful maneuver. The lane changing maneuver is governed by three cyber phases. Author in [19] has proposed a protocol so-called Zebra Protocol to cover up all these cyber phases. Details about these phases are given in the next section (IV-A). Theoretically, the cyber phases, presented there, must be executed by any vehicle tends to perform a lane change maneuver, even a highway first lane entrance, but practically, in some situation, only the first phase can be performed. Briefly, the first phase consists on diffusing a lane changing request. This situation can lead to the following hypotheses:

- The transmitted message m, is lost, and none of the vehicle X surrounding, had the opportunity to receive it, and this case is covered by the study in [19].
- None from the nodes who have received the message m is eligible to serve in this maneuver. So the eligible group is empty. In this paper we focus on this case.

The following use cases, studied in this work, result from the second hypotheses.

After changing its lane, and depending to the global network density, the vehicle X can be inserted in the middle of an existing cohort, in the inter-cohort spacing, or, in a free spacing, typically, the case of low density network.

IV. Cohort Management Distributed Algorithms

A. Middle Cohort Insertion

Let us start, firstly, by describing the procedure followed by the vehicle X to change its current moving lane safely. It is interesting to indicate that the same process is adapted when a vehicle Y is supposed to enter the highway.

We consider the scenario depicted on Figure 2. A vehicle X, member of cohort C', is at the position (x, y) and circulating on lane i, wants to move to the lane i±1. Otherwise, at time τ, X has the coordinates (x, y) and moving with at the velocity on the lane i. At the time $\tau + \varepsilon$, X wants to be at the position (x', y') on an adjacent lane i±1. This scenario is covered by three cyber phases, illustrated on Figure 3, as following:

Phase 1: X informs its surrounding that it wants change its lane and go to an adjacent one. In this purpose, X transmits a message m containing its current situational data at the time τ, called $\omega_\tau(X)$, and the wanted situational data at the time $\tau + \varepsilon$, called $\omega_{\tau+\varepsilon}(X)$. So m has this form; $m = [\omega_\tau(X) + \omega_{\tau+\varepsilon}(X)]$. The message m will be received by all the nodes in the Geocast coverage area of X.

Every vehicle who has received m has to verify its eligibility to positively response to this request. To test its eligibility, each node Y will compare its future situational data (at time $\tau + \varepsilon$) with the requested situational date at the same time. If these information are approximately close, Y announces itself as an eligible vehicle and informs its neighbors. Else Y ignores the message. The eligibility test is performed according to the procedure presented by Algorithm 1. At the end of this cyber phase a group of eligible vehicles is formed, so-called E. This group is marked on Figure 3 by the red rectangle.

Algorithm 1: Eligibility Procedure

```
Data: m ← [ω_τ(X) + ω_{τ+ε}(X)]
      d ← ω_{τ+ε}(Y)
begin
  if ω_{τ+ε}(X) and ω_{τ+ε}(Y) are close then
    // Y declares itself eligible
    eligible ←  true
    // inform the rest of nodes
    generate(m_eligible)
    send(m_eligible)
  else
    // Y ignores m
    discard(m)
```

Phase 2: During phase 2, the eligible group members will cooperate together in purpose to decide the couple of nodes, who will participate practically in the physical phase of this maneuver, by creating the necessary spacing to insert X, this couple are called the actors [19].

This cooperation, is a sort of negotiation between these nodes and it requires the use of a consensus protocol. Agreement protocols are out of scope of this paper, but it is essential to mention that our research is based on the agreement protocol proposed by G. Le Lann in [17]. How the consensus protocol is working is demonstrated on Figure 3. Every node has to disseminate its own proposition, noted for example v_z. In our

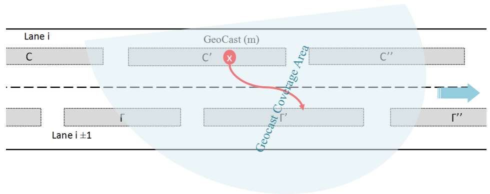

Figure 2. Middle cohort insertion request geocasting.

situation, v_z contains the couple of nodes considered by the node Z to be suitable as actors. The propositions are collected and propagated until reaching the two extremities of the E. When this collecting message arrives to the first (resp. last node) in E, it will be sent in the opposite direction, for example from the last one to the first one, and is-to-it. The messages coming from the E group extremities will be received by a same node and this node will take the final decision and disseminate it to the rest of E.

Phase 3: The actors, here are represented by the couple (Y, Z), will inform X by the decision resulting from the consensus protocols. This cyber phase ends up by triggering the maneuver physical phase.

B. Inter-Cohort Spacing Insertion

Let us consider the following scenario, X performs the geocast and waits, but no response is received. So X deducts that no vehicle is eligible to participate to its maneuver. Then X decides to move to the lane i±1. Consequently, two use cases are possible. After moving to lane i±1, X can be situated between two contiguous cohorts or in a free spacing. Free spacing insertion use case will be detailed in the next subsection, III-C. Hereafter, we focus on the second case. After changing its lane, as depicted on Figure 4, X is actually situated in the inter-cohort spacing, $S_{H/T}$, of two contiguous cohorts, Γ and Γ'. In such condition X must join Γ or Γ', or create its new cohort, if the available space permits, or leave this space if we are facing a compacted network.

In this section we propose a schema helping X to make the most suitable decision, in this situation. Furthermore, we assume that X is the only responsible of its future cohort selection, and this selection is based-on the distance separating X and this cohort. We, also, suggest that X will select the closest cohort, so we proceed as follows:

- Measure the distance separates X and Γ Tail's, so-called $D_{T/X}$, and the distance separates X and Γ' head's, so-called $D_{H/X}$.
- Compare $D_{H/X}$ and $D_{T/X}$, and then make decision.
- If $D_{T/X}$ is smaller than $D_{H/X}$, then X will try join Γ, else X will try join Γ'.

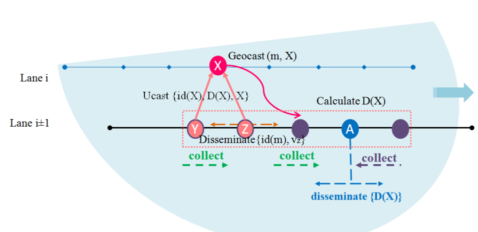

Figure 3. Lane changing maneuver cyber phases demonstration.

This mechanism is presented by the pseudo-code entitled Algorithm 3. After comparing $D_{H/X}$ and $D_{T/X}$, if $D_{T/X}$ is smaller than $D_{H/X}$, (resp. $D_{T/X}$ is smaller than $D_{H/X}$) X will send Cohort Tail Insertion Request to T (Γ tail), (resp. Cohort Head Insertion Request to H (Γ' head)), as shown on Figure 5-b, (resp. Figure 5-a). When the request is received, T (resp. H) must verify if its own cohort is able to support a new member, by checking the constraint of cohort size, $n < n^{\bullet}$. Consequently, the request will be approved only if $n < n^{\bullet}$ is true, see Algorithm 2. Then, X's reaction is depending on T's, (resp. H) reply. So, if the request is accepted, X will proceed according to Algorithm 4, (resp. Algorithm 5);

- X assigns itself a rank $n + 1$, (resp. rank 1).
- Accelerates until $D_{T/X}$, (resp. decelerate until $D_{H/T}$) respects the constraint of inter-vehicular spacing and $D_{H/X}$, (resp. $D_{T/X}$) respects the inter-cohorts gap.
- Sends a message m_x to the rest of the cohort, to help them updating their local data.

Algorithm 2: Request Acceptance Procedure

Data: $n, n^{\bullet}$
Result: *accept*
begin
  if $(n < n^{\bullet})$ **then**
    accept ← true
  else
    accept ← false
  return *accept*

If the request is rejected, X must react otherwise. So, the node has to perform the opposite request. X is going to try to join its successor cohort Γ', (resp. its predecessor cohort Γ), by performing, Cohort Head Insertion Request, (resp. Cohort Tail Insertion Request). And if the request is accepted, X has to proceed as described above. But the worst case condition is when the Cohort Head and Cohort Tail requests are rejected. Accordingly, we propose the following solution: X is going to verify whether, within the available spacing $S_{H/T}$, it is able to create its own cohort. Then, the lower bound of inter-cohort spacing must be respected.

If $SH/T \ll 2 * S^{\circ} + car_{size}$, then X must leave its current location. Leaving the current location can train other type of maneuvers like overtaking, or passing an entire cohort

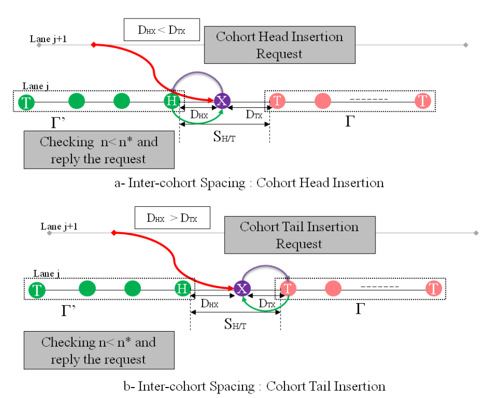

Figure 4. Inter-cohort spacing insertion illustration.

Algorithm 3: inter-Cohort Spacing Insertion

Data: $D_{H/X}, D_{T/H}, S^{\circ}, S^{\bullet}, s^{\circ}, s^{\bullet}$
$S_{H/T} \longleftarrow D_{H/X} + D_{T/H} + car_{size}$
begin
  if $(D_{H/X} \leq S^{\circ} + care_{size})$ **then**
    $r_x \longleftarrow 1$
  else if $(S^{\circ} \leq S_{H/T} 2.S^{\circ} + car_{size})$ **then**
    if $(D_{T/X} D_{H/X})$ **then**
      cohortTailInsertionRequest()
    else if $(D_{T/X} D_{H/X})$ **then**
      cohortHeadInsertionRequest()
  else
    leave()

or even a new lane changing maneuver. Actually, overtaking and passing an entire cohort is out of the scope of this work. In addition, it is interesting to mention that, X is also able to decide to perform one of these options even without performing cohort insertion request.

C. Free Spacing Insertion

Resume the same scenario described in the beginning of the last subsection (IV-B), and as mention there, in this section, we focus on the free spacing insertion use case. After performing its lane changing maneuver, X is located in a low density lane. And in this situation, one of the subsequent sub-cases is able to take pace.

1st sub-case: X goes into an almost empty lane i±1. The vehicle finds itself far away from any cohort. Consequently, X is forced to create a new cohort of size $n = 1$. Then, X is going to declare itself as a new isolated cohort by assigning a rank equal to 1. While respecting the allowed velocity, X has the choice to accelerate/decelerate to join distant cohorts, if they existed, or to keep its current speed.

2nd sub-case: In such situation X is located behind some cohort , as shown in Figure 5-b, and there is no close cohort following it. Or X is located in front of a cohort , as depicted in

Algorithm 4: Cohort Tail Insertion Request

begin
  send(requestToTail)
  wait()
  if *(acceptFromTail == true)* **then**
    $r_x \longleftarrow n + 1$
    if $(D_{T/X} \geq s^{\bullet})$ **then**
      accelerate until $s^{\circ} \leq D_{T/X} < s^{\bullet}$
    send(m_x)
  else if *(acceptFromTail == False)* **then**
    if $(D_{H/T} \leq S^{\circ} + car_{size})$ **then**
      decelerate until $D_{H/T} \geq S^{\circ}$
      cohortHeadInsertionRequest()
    else if $(D_{H/T} \leq 2.S^{\circ} + car_{size})$ **then**
      decelerate until $D_{T/H} \leq S^{\circ}$ $r_x \longleftarrow n + 1$
    else if $(D_{H/T} \geq S^{\circ})$ **then**
      leave()

Algorithm 5: Cohort Head Insertion Request

begin
  send(requestToHead)
  wait()
  if *(acceptFromHead == true)* **then**
    $r_x \longleftarrow 1$
    if $(D_{T/X} \geq s^{\bullet})$ **then**
      decelerate until $s^{\circ} \leq D_{H/X} < s^{\bullet}$
    send(m_x)
  else if *(acceptFromHead == False)* **then**
    if $(D_{H/T} \leq S^{\circ} + car_{size})$ **then**
      accelerate until $D_{H/x} \leq S$
      cohortTailInsertionRequest()
    else if $(D_{H/T} \leq 2.S^{\circ} + car_{size})$ **then**
      accelerate until $D_{T/x} \leq S^{\circ}$
      $r_x \longleftarrow 1$
    else if $(D_{H/T} \geq S^{\circ})$ **then**
      leave()

Figure 5-a, and there is no cohort ahead. In both possibilities X has to join . Thus, we have, like in Section IV-B, either cohort tail insertion request, or cohort head insertion request, or also create a new independent cohort, with respect to the inter-cohort gap constraint. The main algorithm, solving this use case is presented by the pseudo-code, so-called, Algorithm 6.

In fact, within this use case X has more freedom to decide to create a new isolated cohort or to try to join the existing one. So, this use case is tightly close to X desire more than the constraint of available space, like the preceding subsection. Then, X behavior can be described as follow:

- X decides to create a new cohort, then, according to its location, X decelerates/accelerates to create the necessary inter-cohort gap, and assigns itself rank 1.
- X decides to join existing cohort, so, depending to its current location, X will send cohort tail or cohort head insertion request.

As described above, X will send a cohort tail insertion request to T, (resp. cohort head insertion request to H). Then, T (resp. H) treats the received request according to Algorithm 2, and sends its reply to the requestor. According to T's response, (resp. H's response), if the request is accepted, X

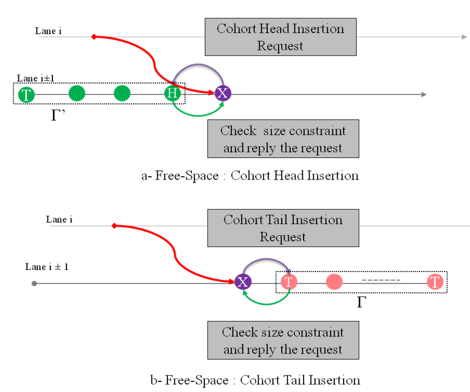

Figure 5. Free space insertion illustration.

Algorithm 6: Free Spacing Insertion Algorithm

```
Data: D_{H/X}, D_{T/X}, S°, S•
begin
    if (X decide to create new cohort) then
        if (X is behind ) then
            decelerate until S° ≥ D_{T/X} ≥ S•
        else if (X in front of ) then
            accelerate until S° ≥ D_{H/X} ≥ S•
    else if (X decides to jion an existing cohort) then
        if (X behind ) then
            cohortTailInsertionRequest()
        else if (X is in front of ) then
            cohortHeadInsertionRequest()
    else
        leave()
```

Algorithm 7: Free-Space Cohort Tail Insertion Procedure

```
begin
    send(requestToTail)
    wait()
    if (acceptFromTail == true) then
        r_x ⟵ n + 1
        if (D_{T/X} ≥ s•) then
            accelerate until s° ≤ D_{T/X} < s•
        send(m_x)
    else if (acceptFromTail == False) then
        decelerate until D_{T/H} ≤ S°
        r_x ⟵ 1
```

Algorithm 8: Free Space Cohort Head Insertion Procedure

```
begin
    send(requestToTail)
    wait()
    if (acceptFromHead == true) then
        r_x ⟵ 1
        if (D_{T/X} ≥ s•) then
            decelerate until s° ≤ D_{T/X} < s•
        send(m_x)
    else if (acceptFromHead == False) then
        accelerate until D_{T/H} ≤ S°
        r_x ⟵ 1
```

will proceed according to Algorithm 7, (resp. Algorithm 8).

The major difference between cohort head and cohort tail insertion procedures proposed for this use case and the ones described in the above section is the impact of space available for X to react. In such case, X has sufficient space to act freely.

V. Conclusion

In this paper, we explained the need to structure the IVN into fully-distributed and bounded-size vehicular strings named cohorts. These cohorts, cyber-physical systems based on short-range neighbor-to-neighbor directional communications, are purposed to alleviate as much as we can the complexity of vehicular environment and to ensure the road traffic safety, and to minimize dramatically the collision and interference problem. In this scope, we proposed, in this work, several algorithms to manage the vehicular behavior within several use cases, and for that we focus on the lane changing maneuver. In our future work we focus on implementing and testing these propositions.

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