Context-Aware Routing and Forwarding Model for NDN-Based VANET

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Abstract. Routing in Vehicular Ad hoc Networks (VANET) is a challenging topic due to the links intermittency, which in turn makes it difficult to manage routing tables. One solution is routing table management avoidance and the adoption of flooding. This solution is adopted by many state-of-art proposals. However, it can degenerate to broadcast storm problems. Some proposals leverage the characteristics of Named Data Networking (NDN) to improve VANET. They use the Forwarding Information Base (FIB) to manage routes, but flooding is still the main mechanism used to update FIB when nodes move from one to another location. These solutions neither take advantage of the in-network caching, nor adapt routing to VANET context.

Each VANET context presents different routing requirements, thus, a context-aware routing and forwarding model that uses FIB to manage routes is proposed. A mobility prediction mechanism is adopted to update FIB and the list of neighbor. Additionally, all overheard packets are processed in order to update the neighbors list and, thus, avoid frequent broadcasts. To take advantage of the in-network caching, nodes share their list of cached contents when responding to a special request from RSU, querying for new content sources. To attain this objective, modifications of the NDN structures are performed.

An improved performance of VANET is expected, at a cost of an increased computational overhead due to the processing of all overheard packets, and the mobility prediction.

Keywords: Caching · Named Data Networking · Routing · Vehicular Ad hoc Networks

1 Introduction

The development of Intelligent Transportation Systems (ITS) [18] is intimately attached to the development of vehicular communications, and particularly Vehicular Ad Hoc Networks (VANET). In turn, the development of vehicular communications presents specific challenges due to their intrinsic characteristics

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such as frequent network partitioning, highly dynamic topology, and short-lived links between nodes.

State-of-the-art routing and forwarding in VANET are mainly geographic or topology based. Topology-based solutions resort to flooding in order to acquire topological information. Geographical solutions also resort to flooding when the content source moves. Network flooding is a solution that should be avoided, because it is ineffective in terms of resource management and can result in the broadcast storm problem, compromising the traffic and the network efficiency.

Named Data Networking (NDN) [29], a new Internet architecture, identifies the contents by their names instead of their relative location (i.e., the IP addresses). This characteristic (i.e., name-based content identification and routing) brings another important architectural advantage of NDN - the in-network data caching that augment the sharing capacity of the nodes. Additionally, NDN forwarding plane is stateful and adaptive [26], giving this architecture the capacity of controlling and avoiding packet loop.

A context-aware NDN-based routing and forwarding mechanism for VANET is proposed in this paper. The context-awareness is based on the application type and the communication model in use. Additionally, the model distinguishes pull- and push-based messages. We propose a hybrid (geographic and topology-based) routing model, in the sense that the model will leverage all overheard packets to extract topological information and the geographical location of the node will be used to forward packet to specific nodes in the network. To further avoid or reduce the need of flooding, a mobility prediction algorithm will be used. The main task of the mentioned algorithm is to predict routes of the moving nodes, avoiding frequent broadcast of beacon messages. The internals of the mobility prediction mechanism are not discussed here. Whereas the routing mechanism will be responsible of proactively maintaining an updated Forwarding Information Base (FIB) for a relatively long-term base, the proposed forwarding strategy will maintain updated the list of neighbors and will take advantage of in-network data caching to avoid flooding. Differently from studies such as [8], which allow caching of all unsolicited Data, we select unsolicited Data based on their application type: push-based, safety, and all short-lived messages are not cached.

To attain these objectives, the following NDN main structures are modified: Pending Interest table (PIT) to include the previous node forwarding the packet; the FIB, to include Node Mobility Status Information - NMSI (i.e., the node ID, node speed, node geographical coordinates, direction, and timestamp); the NDNLPv2 [16] packet (LpPacket) headers are extended to include the node mobility status information (for Interest and Data packets). This information is extracted in each node receiving the packet and is used to update the list of neighbors; a link adaptation layer is proposed to incorporate the specificities of the ad hoc vehicular network.

The remaining of this paper is organized as follows: Sect. 2 presents the related work. Section 3 presents the model design including the proposed mechanism for content discovery, the forwarding strategy, and the routing protocol. Section 5 presents the summary and discussion of contributions.

2 Related Work

The high mobility of VANET nodes results in an highly dynamic topology and intermittent connectivity. These are the main constraints that make it difficult or even infeasible to run a routing protocol in VANET [8]. Several efforts, however, have been put forward to overcome such difficulties and develop routing solutions for VANET.

Authors in [8] use a complex mapping of geofaces and geographical areas, where to forward the Interests towards the corresponding contents. Having reached the geographical area, the Interest is then flooded.

Authors in [28] propose a proactive opportunistic routing mechanism that keeps track of content locations using last encounter information location. The vehicles periodically advertise to one-hop neighbors to collect the summary of all contents in the node. The same authors propose in [24], a vehicular information network architecture with a push-based mechanism, for content dissemination. The study also proposes a naming scheme and a proactive location-based routing.

Taking advantage of computing, caching and communicating vehicle capabilities, [15] proposed a routing mechanism that confines the broadcast of Interest/Data to most important vehicles. In this way, the information is be available within the vehicles with higher centrality score. To identify important vehicles, which are responsible for efficient content distribution, the authors use their previously proposed mechanisms that enable each vehicle to autonomously find its own importance in the network.

In [12], the authors propose a routing protocol that initially floods the network to populate FIB, and then forwards packets based on the previously populated FIB. This mechanism is somehow similar to the solution proposed by [20] for wired networks. An Interest is periodically broadcasted in order to discover new paths and new content sources. The proposed solution identifies nodes by their MAC address, and in [13] they extend the previous solution, extracting the Face MAC address from the NDN strategy layer. In [9], the same authors propose a V2I communication architecture also based on NDN, which is then extended to support V2V communications. The proposed solution works in two different routing approaches, one where requests are forwarded to the RSU and another where the RSU is defined as a backup network component. Additionally, they propose in [10], a routing protocol that assumes each vehicle having a set of unidirectional antennas, used in unicast transmissions to forward the messages in a specific direction. To support vehicle mobility, the solution includes a forwarding mechanism that uses timers in each vehicle to identify unsatisfied requests. When a timer elapses, the vehicle re-transmits its request through another path. In [11] they present the details of [10], including its performance evaluation.

A routing protocol is proposed in [23]. The solution combines data-name-based routing and host-ID-based routing to address the mobility issue and the broadcast storm problem from NDN flooding solutions. In the referred work, nodes request data by their content name, then, knowing the content location, the ID-based routing is triggered. Using the corresponding position the protocol computes the route towards the destination host. When the content provider is unknown, a flooding process takes place.

In [4] a protocol that reduces broadcast storm by using a defer timer (packet holding time) is proposed. The protocol prioritizes Interest transmissions among neighbor nodes, avoiding packet re-transmissions.

In [6], the authors propose a model in which vehicles periodically notify neighbors about their cached content and maintain a local table containing neighbors' cached contents. When a route disruption occurs, the solution resort to a distance prediction algorithm to calculate the next hop. The presented protocol is topology-based and works proactively.

A reactive routing protocol is presented in [27]. The proposed solution categorizes Information-Centric Networking (ICN) content into: 1) popular public data services, 2) popular private data services, and 3) unpopular data services. Arguing that for each of these categories, it may be necessary to choose an appropriate routing design, the authors designed a Bloom Filter (BF) based routing protocol for popular data services (1 and 2). The nodes in the corresponding clusters periodically summarize the content to create their own BF (content digests), which are then used to advertise (by flooding) the local content of the partition where they belong to.

As shown above, the majority of these proposals resort to flooding for content discovery, dissemination, and for recovering from route disruption. Additionally, they resort to constant broadcast of beacon messages to create and maintain a list of neighbors. To maintain an updated list of neighbors a protocol should increase the frequency of beacon broadcast, which results in an increased network traffic, and consequently collisions and delays in delivering packets.

The result of a literature review performed in [21] indicates that although some proposals applied NDN-based routing and forwarding for VANET, none of the surveyed solutions considers the different network scenarios (e.g., highway, rural or urban environment), the different applications (e.g., safety/emergency, efficiency or entertainment) and do not adapt the solution to the network characteristics where the model is applied, i.e., they are not context-aware. In addition, none of them included mobility prediction to help updating the list of neighbors and in selecting better relay nodes for packet forwarding, in order to avoid or reduce broadcast. Moreover, these solutions do not leverage the in-network data caching for routing decisions. Actually, the study by [6] considers the use of in-network caching for content discovery but, does so by allowing each vehicle in the network to perform flooding, requesting each other node to share the list of their cached content, a solution that can overload the network traffic.

Table 1 presents the comparison summary of state-of-the-art solution, and the main difference with the solution proposed in this work.

Table 1. Main contributions and differences from state-of-the-art solutions

Propriety	References	Existing solution	Our contributions
Content discovery	[4, 10, 12, 13, 15, 23, 24, 27, 28]	Flooding	Flooding (rural scenario); RSU beaconing (urban scenario), flood if no route to RSU, and no corresponding entry in *Cached Content Table* (CCT)
	[9]	Flooding (decentralized approach); RSU beaconing (centralized approach), wait if no route to RSU or to the content source	
Neighbor status	[4, 10, 12, 13, 15, 23, 24, 27, 28]	Maintained by 1-hop beacon broadcast, from all nodes	Maintained by 3-hop beacon broadcast, from RSU (urban scenario), and 1-hop beacon broadcast from all nodes (rural scenario). Normal traffic leveraged to gather neighbor status, by including control information onto the Interest/Data NDNLP packet header
Routing enhancement feature	[6]	Caching (periodic beacon broadcast from 1-hop nodes, to share cached content list), and distance prediction method (reference to this method is unreachable)	Caching (Sharing of cached content list from any node), and mobility prediction
Context awareness	[9]	Communication mode (V2V, V2I)	Dissemination mode (push-, pull-based); application type (active safety, efficiency, comfort, interactive-entertainment); network density (rural, urban); and communication model (V2V, V2I)
Content caching	[7]	Cache all content (including all unsolicited Data)	Selective unsolicited Data caching, depending on application type (*drops*: all push-based, *caches*: (1) solicited safety, (2) comfort, and (3) some long-lived interactive-entertainment application)
Beacon broadcast	All	Periodic (frequent) from all nodes	Periodic (less frequent) from all nodes (rural scenario), only RSU (urban scenario). All overheard traffic (not dedicated beacons) leveraged to distribute control information, and reduce the frequency of beacon broadcast

3 Proposed Model Design

In this work, a context-aware routing and forwarding model designed to take mobility prediction in consideration, is proposed. The main goal is to forward packets to specific nodes which trajectories are known, and avoid broadcast whenever possible. In-network content caching is also explored by means of an process initiated by the RSU, in which all nodes along the forwarding path, from the RSU to the content source, share their list of cached content.

The context-awareness is firstly based on the type of communication (i.e., pull- or push-based). Based on the classification adapted from [5], four classes of VANET applications are considered: active safety, efficiency, comfort and interactive-entertainment. These classes are grouped by communication model (i.e., V2I or V2V), region of interest (i.e., small, medium or large), delay sensitivity (i.e., delay tolerant/sensitive), frequency of message transmission, traffic volume, and content validity period. Communication requirements for each of the aforementioned grouping classes are different, thus requiring different routing/forwarding mechanisms.

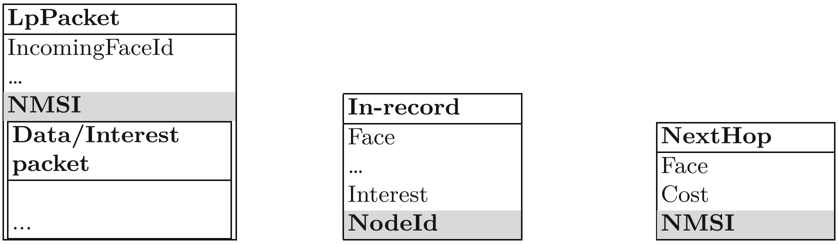
3.1 Main Modifications to the NDN Structures

The wireless channel is broadcast-based by nature, i.e., each node within the communication range of the sender node will overhear the sent packets. This characteristic can be exploited to reduce the need of broadcast in updating the list of neighbors, as it is done by several state-of-the-art studies, and to learn about new content sources. In order to take advantage of the overheard packets, all NDN packets will be extended to carry additional (optional) control information (i.e., the node mobility status information, mentioned earlier). The inclusion of this information is optional in the sense that whenever necessary, the model can fallback to the normal NDN operational mode, flooding the network to discover new neighbors and new content sources. This information is appended to all (Interest and Data) NDNLP packet header, see Fig. 1a, instead of modifying the network layer packet header.

In wired NDN, when a solicited Data is received, PIT is searched in order to find the Face where to forward this Data to. The Face unambiguously identifies the next hop where the packet should be forwarded to. VANET is essentially based on wireless communications. In this network when a node sends a given packet, the packet is overheard by all nodes within the sender's communication range. Thus, the Face-based communication mechanism does not work for wireless channel. To overcome this, and be able to identify the node where to forward the packet to, the ID of the node is included in the corresponding PIT entry, alongside the Face, see Fig. 1b. A good candidate for node identification is the Mac address of the Faces (i.e., net devices) installed on these nodes. Some representative studies that use MAC addresses to identify nodes, include [9,13,14,17].

Similarly, FIB is extended with the NMSI, see Fig. 1b, that will lately be updated by a mobility prediction algorithm - a topic for future work.

Figure 1 shows how the aforementioned three structures are modified.



(a) Inclusion of NMSI into LpPacket header

(b) Inclusion of Node ID into PIT's In-Record field

(c) Inclusion of NMSI into FIB's NextHop field

Fig. 1. Modifications to the NDN structures

A new table - Cached Content Table (CCT) - is added to the NDN structure. The table is used in each node to catalog all cached Data, complementing the CS functionality. Each CCT entry is composed by the Data prefix and the node mobility status information. The node mobility status information refers to the status of the last node from where the packet was received.

Given that NDN is designed for wired networks, besides the aforementioned modifications and to complement them, a link adaptation layer between the network layer (NDN) and the Data-link layer is developed, in order to accommodate the specificities of VANET. This adaptation layer is responsible for building and maintaining the list of neighbor, from all the overheard packets, as explained latter. In addition, the NMSI is attached to the outgoing packets at this layer.

3.2 Content Discovery Mechanism

When FIB in each node is empty, or when new content still not registered in FIB is solicited, a content discovery process takes place. This process populates FIB differently for rural and urban environments.

Discovery in Urban Environments. Urban environments are characterized by static infrastructures, which can be the Road-side Unit (RSU) or Base Stations (BS). The geographical location of these nodes are persistently stored in the FIB of all nodes in the network.

Periodically, each RSU broadcasts a beacon message to query new content sources. On response to this beacon, the content sources advertise their contents via a special packet - sData, which is sent back to the RSU. sData is destined to the RSU but all the intermediate nodes receiving this packet register the announced prefix and the list of cached content from the previous node, and then append their own list of cached contents. That is, the in-network caching is leveraged but, instead of allowing all vehicles to broadcast their list of cached content, as proposed in [6], for instance, a request-based mechanism from the RSU is adopted and only the vehicles on the path from the content source to the RSU will be allowed to share their list of cached contents.

The periodicity of the RSU beacon broadcast will be defined based on the periodicity of the updates performed by the mobility prediction algorithm. This way, the frequency of broadcast will be fixed lower than the state-of-the-art solutions.

Discovery in Rural Environments. Rural and other environments not equipped with static nodes, can not efficiently benefit from the mechanism proposed for the urban ones. In these environments a content source producing a new content will immediately announce this content. Additionally, content sources announce content whenever a predefined timer elapses. The timer is set to an ideal value resulting from the experiments, and it will be based on the periodicity of the RSU beacon broadcast. For instance, the timer can be equal to 3 times de periodicity of beacon broadcast. If a packet form RSU is not received during 3 times the fixed periodicity of RSU broadcast, vehicles in rural environment announce their prefixes.

3.3 Forwarding Strategy

For packet forwarding, NDN forwarding plane uses the information stored in FIB. However, differently form TCP/IP networks, NDN forwarding plane is stateful and intelligent, in the sense that it is able to make per node decisions about the preference and the usage of existing routes based on their performance and status. Although NDN-based local networks can work without a routing protocol given the intelligence of the forwarding plane - which can detect and recover by itself from any situation of network failure [29] - the need for routing is exhaustively investigated and justified in [25]. In our design, depending on the message type, the forwarding plane can process the received message without using routing, as explained in the next sections.

The following sections present incoming Data and incoming Interest processing in each NDN node.

Processing for Incoming Data. As presented in Algorithm 1, on packet reception the model verifies if it is a solicited Data or not. Unsolicited Data can be either an overheard pull-based or push-based message. The push-based messages belongs to the safety/emergency class, and in this case the Data is broadcasted after its validity is verified. This type of messages is not processed in PIT or FIB, and is not stored in cache. The reasoning behind this, is the fact that these messages are urgent and short-lived.

Efficiency related messages are generally solicited and also short-lived, therefore are broadcasted and not stored in cache. Comfort and Interactive-entertainment related messages are processed as usual in NDN. In addition, we propose the registration of the received Data in the CCT. This way, future requests for the same Data can be redirected to the nodes holding the Data, based on the information held by this table.

Other unsolicited Data, but not push-based, is stored in cache only if it is classified as long-lived. Otherwise, the Data is discarded.

Algorithm 1: Incoming Data processing

```
Input : destId: Next hop node ID;
        NMSI: Node Mobility Status Information
if (Push-based Data) then
    if (Data still valid) then
        Broadcast (Data)
    else
        Discard_Data ()
else
    if (Corresponding Interest exists in PIT) then
        if (Efficiency-related Data) then
            Broadcast (Data)
        else
            Forward (Data, destId)
            Add_To_CS (Data)
            Update_CCT (Data-Prefix, NMSI)
    else
        if (Long-lived Data) then
            Add_To_CS (Data)
            Update_CCT (Data-Prefix, NMSI)
        else
            Discard_Data ()
```

We propose a scheme where all safety-related content, which is also push-based, will be based on the following prefix:

/push-based/info-type/sender-ID/sender-geo-coordinates/

The first component is used to identify the type of content as being push-based, and destined to broadcast. There can be different types of push-based content. For instance, besides the active safety content there is the content related to road efficiency. The latter is longer-lived than the former, thus, they can be treated differently. This is the reasoning behind the distinction provided by the second component. The third component is the identification of the sender, and the last component is the geographical location of the sender. It is important to have the geographical coordinates of the sender, given that safety content is location-dependent. The broadcast information is only important a hundreds of meters away from the location where it has been sent (i.e., it has a medium region of interest), therefore the model fixes the hop limit to 1.

Processing for Incoming Interest. When an Interest is received, a CS lookup procedure takes place like in the standard NDN. When no corresponding Data is found in CS, a PIT lookup procedure is performed. If a PIT entry exists but from a different incoming Face, the new request is aggregated to the existing pending Interest. If no pending Interest is found, the new Interest is added to PIT. If the Interest is related to the efficiency application class, then it is broadcasted, as it deals with the delay-sensitive content.

If the received packet is related to the comfort or interactive-entertainment application class, then a FIB match is performed. In case that the Interest matches a FIB entry, it is forwarded using the predicted routes, as presented in Sect. 3.4. Otherwise, its corresponding content still needs to be discovered. Apart the mechanism presented in Sect. 3.2, when a new content discovery is to be performed, the following procedure takes place.

In urban environments and for comfort and interactive-entertainment applications classes, the model follows a mechanism similar to the proposed in [9], where the Interest is forwarded towards the RSU which is supposed to have a broader knowledge about other existing routes. However, differently from that study, our solution does not awaits the creation of FIB entry, it broadcasts the Interest. Before the Interest is broadcasted however, a last feature is explored - the usage of known cached contents from other nodes. In this procedure, a CCT lookup is performed and when a match is found the Interest is forwarded accordingly. When no match is found, the Interest is broadcasted.

Algorithm 2 describes the intermediate node processing for an incoming Interest.

3.4 Routing Protocol

Routing protocols are responsible for initiating and maintaining routes to facilitate multi-hop communication. Routing populates and keeps FIB updated.

Several forwarding proposals for NDN-based VANET are based on flooding (blind flooding), and include a particular scheme to control the rebroadcast, e.g., resorting to distances to the content provider, and timers to defer the subsequent broadcast. This mechanism have the advantage of simplicity, does not require the knowledge about the neighbor nodes, and does not require the usage of FIB. However, it generally results in problems such as the traffic congestion, packet collisions, or delivery delays due to the broadcast storm problem [7,19,22].

A relatively more intelligent alternative apart the broadcast and the use of defer timers and distances, is the identification and selection of possible relay nodes by using unicast communications [2,3,9,11,12,17]. This approach requires an updated knowledge of the node's neighbors geographical location, from which the better relay between the current node and the content source can be selected. This mechanism can reduce the traffic congestion, collision and delivery delays, as demonstrated in [1], for specific case of MANET. However, some kind of beacon broadcast is still necessary to maintain an updated list of the neighborhood, as used by the majority of state-of-the-art proposals, see Table 1. We claim, as

Algorithm 2: Incoming Interest processing

```
Input  : prevId: Previous node ID;
         destId: Next hop node ID;
if (Data exists in CS) then
    ReturnToRequester (Data, destId)
else
    if (Interest exists in PIT) then
        Aggregate (Interest)
    else
        AddToPITEntry (Interest, prevId)
        if (Efficiency-related Interest) then
            Broadcast (Interest)
        else
            if (Interest matches FIB entry) then
                Forward (Interest, destId)
            else
                if (Data-prefix in CCT) then
                    Forward (Interest, destId)
                else
                    if Urban scenario then
                        Forward_To_RSU (Interest, destId)
                    else
                        Broadcast (Interest)
```

a hypothesis, that this issue can be mitigated by using some alternative mechanisms such as the mobility prediction and/or by leveraging the overheard packets to extract the neighborhood-related information (see Sect. 3.1), as proposed in this work.

Whenever an intermediate good candidate for relay exists, it will be selected to forward the messages.

Algorithm 3 describes the routing process in place on vehicles and on the RSU. As explained in Sect. 3.2, in urban environments the RSU broadcast beacon messages for content discovery. On response of the beacon message, or on a self initiated content announcement from the content source in rural environment, the content sources send back a special Data (sData) that carries an Prefix Announcement (PA). If a packet holding the prefix announcement is received in a node, a FIB entry is created or updated. As referred earlier, besides the PA, FIB will also include the NMSI which for this case is related to the content source (NMSI-CS). If the received Data packet is unsolicited and does not include a PA, then a data prefix is extracted from this new packet and a FIB entry is created. In this latter case, the NMSI is related to the intermediate node from which the packet was received (NMSI-IN).

A periodic time triggered mobility prediction process takes place in each node. Neighbors are mobile nodes and the model should avoid beacon broadcast whenever possible. Therefore, a Short-Term Mobility Prediction (STMPA) to track and update the current location of a neighbor is used. Additionally, a Long-Term Mobility Prediction (LTMPA) - deployed only on static nodes, example the RSU - is used to track the trajectory of vehicles.

Routes in FIB are periodically updated by: 1) the mobility prediction algorithm; 2) the updates from the RSU periodic beacon broadcast process; and 3) from the control information extracted from all overheard packets, in each node.

Algorithm 3: Routing process

```
Input : PA; NMSI-CS; NMSI-IN; DP: Data-Prefix;
if (New packet received) then
    if (packet holds a Prefix Announcement) then
        CreateOrUpdateFIB (PA, NMSI-CS)
    else
        CreateOrUpdateFIB (DP, NMSI-IN)
    ExtractNeighborhoodInfo ()
    UpdateListNeighbors (NMSI-IN)
// Time triggered mobility prediction
if (processing for vehicles) then
    UpdateListNeighbors (NMSI-IN, STMPA)
    UpdateFIBNext-Hops (NMSI-IN, STMPA)
else if (processing for RSU) then
    UpdateFIBNext-Hops (NMSI-CS, LTMPA)
```

4 Security Considerations

IP-based networks provide security by creating and securing the point-to-point channel between the hosts. That is, instead of the packets, the communicating channel is secured. NDN, on the other hand, have security built into the network layer. Each content producer includes its signature and other authentication information in each Data packet before sending it through the network. That is, protection and trust are embedded in the Data packet [29]. The consumer receiving the Data verifies and accepts the Data if the signature is authentic. The Data security and integrity in the proposed model relays on this mechanism. Our model allows intermediate nodes to extract the list of cached content of the previous node, from the received Data. When an intermediate node receives a Data, it copies the received Data to extract the aforementioned list, then it includes its own list. It encapsulates the copied Data including the list of cached content in a new Data packet, and then it signs and authenticate the packet before sending it back into the network. By allowing nodes to modify the Data packets in order to include their list of cached content, our model is prone to attacks, where a malicious node can mislead the network by injecting false pair of PA and NMSI, redirecting the network traffic. As mentioned, the solution adopted in this work is to force each node that modifies the received Data packet to sign and authenticate the packet after the inclusion of its own list of cached content, encapsulating the Data from the previous node. We highlight that only the Data sent by content source in response of the RSU periodic broadcast can be modified as described above in this section.

5 Summary and Discussion of Contributions

The model is currently being evaluated as first step, by means of simulation. ndnSIM and Simulation of Urban MObility (SUMO) were selected to be used for simulations. The simulation results are extracted and statistically analyzed, using either MATLAB or R environment. The results are not included in the present paper, and will be presented in future. Our intention here is to present the idea under development.

In summary, the changes proposed to the NDN structure are: a) Inclusion of a *link adaptation layer*: to adapt the NDN architecture from its wired nature to wireless and ad hoc, the base for vehicular communications. This layer is responsible on maintaining the neighborhood list, and to piggyback NMSI to the outgoing packets; b) *the CCT*: to allow to catalog cached content of other nodes; c) *inclusion of nodes ID*: to allow the identification of wireless nodes, which are not well identified by the Face system; d) *the node mobility status information (NMSI)*: included into the NDNLP packet headers, used for mobility tracking; e) *fields included in PIT and FIB*: used in parallel with NMSI and node ID, to forward messages to specific nodes, to avoid the need of flooding. With this proposal we expect an overall improved performance of VANET, at a cost of an increased computational overhead due to the added complexity for the processing of all overheard packets, which is performed to extract neighborhood information and predict the location and the nodes's trajectories.

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