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Survey of Content Naming Schemes in Vehicular Named Data Network

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***Abstract*— Vehicular Ad-hoc Networks (VANETs) has been one of the hot topics for the researchers, industries and academia for the past few decades. However, current IP based architecture is not able to cope up to the demands and researchers have looked out for ways to extend VANET architecture. Two possible collaborations which are strongly focused include Software Defined Networks (SDN) and a paradigm which is considered as part of future internet architecture Named Data Networks (NDN). The NDN architecture provides an edge because of the fundamental working principle, wherein the content is addressed rather than the host. Although, Vehicular Named Data Network (VNDN) is a relatively new field, the advantages it brings about has urged the researchers to explore it more. There are a few issues like content/data forwarding, routing strategies, naming schemes, channel constraints and adding security to the content without increasing overhead, creating gateways an standardization. The paper focuses on various content naming schemes employed in named data based vehicle networks.**

Keywords*— *Content naming, hierarchical, flat, hybrid, geo-location, Quality of Service (QoS)

I. INTRODUCTION

One of the major applications of wireless network technologies which has gained attention of researchers across the world is wireless ad-hoc communication, VANET. Initially, VANETs was envisioned to help in improving driving safety, traffic management, detect crashes, and facilitate emergency services through reliable and timely dissemination of alert/warning messages among all the connected vehicles [1, 2]. In few developed countries like Japan, Vehicle Information and Communication System (VICS) has been launched [3], primarily used to disseminate information about traffic among all the vehicles on road. The traffic data from all roadside sensors is transmitted to a centralized server and the data is disseminated to vehicles from the server. Although a centralized data processing system has advantages, it has a few shortcomings as well. Firstly, there is a long delay experienced during the process of data acquisition disseminating between road sensors and central server. Second, due to the mobility and scalability of vehicles, real time information delivery is not smooth. Thus, one of the prominent issues in VANETs is data dissemination approach.

Several researchers have focussed on data dissemination methods over the current TCP/IP implementations [4,5,6]. These methods succumb to failure resulting in huge packet loss when the traffic density becomes scarce. Maintenance of paths in extreme dynamic vehicle environment due to IP address assignment for vehicles is difficult and it affects the data dissemination in terms of safety, distance and time. The connected vehicle technology is not only focussed on traffic information dissemination, but is also expected to satisfy the increasing data demands of users on the move, which has led to transit from V2V to V2X (Vehicle to Everything) interactions. Applications of connected vehicle technology demands distribution of large chunks of data among users under circumstances like high mobility, low power requirements, intermittent connectivity and poor infrastructure [7]. The underlying technology of vehicular communication is Dedicated Short Range Communication (DSRC) protocol along with Wireless Access in Vehicular Environment (WAVE). Vehicle communication framework poses some major requirements like scalability, storage and caching mechanisms, mobility characteristics, security and privacy and traffic patterns [8].

II. HOST-CENTRIC TO CONTENT-CENTRIC NETWORKS

TRIAD project pioneered the CCN project, wherein an additional content layer was introduced. The main functionality of this layer includes routing and caching policies based on the name of the content [9]. Several architectures have been developed based on the same concept with an aim to use the internet for better information dissemination and retrieval schemes rather than support only end to end communication as in case of TCP/IP.

The core principle of all these architectures mainly relies on naming the contents. Chunks of data are assigned a name and these data are retrieved without addressing the hosts which produce the data. The nodes act as routers, producers and receivers. The contents are uniquely identified by specialized naming schemes, which are independent of the type and location of the producer. One clear advantage this method gives over traditional IP based technology is that the content serving is enough and the entire communication channel need not be secured or monitored. Additionally, the data packets can be cached by the nodes, so that it is accessible for further incoming similar requests.

Replacing TCP/IP with ICN architecture provides advantages in the fields of mobility, application, security, privacy and scalability [10]. Vehicular applications like traffic management, road safety, alert message and infotainment are mainly interested in the information rather than the location or the identity of the producer/forwarder. Also, the data produced in most cases are intended not for individuals but group of users. It can be observed that naming the content and routing strategies based on the name is a better approach as compared to the existing IP architecture.

Traditional host-centric networks show random behavioral changes in mobile environments. Concepts like mobile IP are introduced to VANETs to tackle the issue, however it only adds to the complexity and the results are not satisfactory [11]. In case of highway environment, the vehicles travel at high speeds and in urban environment, due to increase in number of vehicles, buildings and other obstacles, signal propagation is adversely affected. Named data eases this problem of mobility and properties like in-network caching of data facilitates the users to retrieve data from a nearby storage point or producers. This method ensures reduction in network traffic and latency, since the user need not send packets all the way to the original producer of the content. Scenarios wherein there are disconnected areas and intermittent connectivity can be handled through data muling techniques supported by ICN.

In vehicular communication, the users are mobile and fluctuate often. The trustworthiness based on content is more relevant as compared to the history of the producer [12]. By nature of ICN, the content is secured and not the entire channel of communication. This reduces the overhead of securing the connection and mechanisms can be implemented to secure the packets not the communication path.

A. Research Challenges of vehicle networks

There are major research challenges in each layer which needs to be addressed in case of vehicle network architecture. Application Layer protocol must be able to discover the data, store it when required and update all the relevant data throughout the network [13]. Effective naming schemes and addressing schemes are to be developed to satisfy the increasing demands. In some cases, geo-location information needs to be encoded along with names and time stamping data. The naming schema developed must be in accordance with the addressing techniques [14]. Another major issue is to index the data from the physical world for convenient caching and data dissemination.

Conventional transport layer functionalities like error detection/correction, flow control, congestion control, retransmission of lost data, effective bandwidth management are mostly applicable to end to end transmissions. ICN paradigm does not consider end to end transmissions, since the end points are unknown until the actual time of data dissemination. Thus, there is a need for the transport layer to remove the dependency on end points. Due to the concept of in-network caching, user can retrieve data from any or multiple sources [15]. The challenge is to provide the services of transport layer under circumstances wherein the source of information is not known in advance. Another aspect to be considered is to provide authentic data without revealing the producers identity.

Network layer poses few challenges for information dissemination in vehicular environment. Literature from the past decade has witnessed few dedicated protocols to tackle the mobility issue namely Mobility Centric Data Dissemination algorithm, Vehicle Assisted Data Delivery among others which aimed at improving data delivery in mobile environments. Few researchers considered road requests and GPS co-ordinates to account for mobility during packet transfer [16]. In case of ICN, routing has to be done without prior knowledge about source and destination. Another issue is, data many be combined and transmitted together, which are destined for different locations.

Link Layer has responsibilities like reliability, scalability, receptiveness and adhere to the changes in vehicle environment [14]. Reliability and scalability are interrelated and becomes critical in case of security, safety and selection of access points. MAC management and Address Resolution Protocol along with timeout mechanisms are major challenges in case of ICN. All these issues lead to bandwidth under-utilization, unexpected start-up delays which are inefficient in highly mobile environment.

B. Related Work on NDN

In 2006, Van Jacobson, presented the architecture of named networking content publicly [17]. Later in 2010, NDN project was announced, which is an upgraded version of CCN architecture [18]. The NDN project proposes a transit from the traditional IP architecture to centric architecture. NDN architecture promises to satisfy the future internet model demands.

Over the last 5 years, several researchers have made efforts to adapt NDN into VANETs, which ensures a shift in the paradigm form host-centric to content centric for vehicular environment [19]. In case of VANETs, every node or vehicle needs to be assigned a unique ID mandatorily and the source node makes use of these IDs to identify the destination node [20]. Next, a secure channel is established between the host and destination node, in order to communicate any critical information. Mobility management becomes a major issue, since it is tedious task to maintain the same IDs and communication path [21]. Vehicular applications majorly require ‘content’, without considering the location or host identity. This has motivated the research fraternity to adapt NDN into VANETs for increasing the network performance. Authors in [22] have adapted NDN into ad-hoc networks and pointed out towards a promising architectural direction to enhance network performance and provide effective solutions for vehicle environment.

Similar efforts have been made to adapt NDN into V2V communication. The aim was to transmit traffic data in a rapid and reliable way [23]. The authors have adapted techniques like naming the data and designing name data forwarding mechanisms. The results show that the data transmission is faster and reliable in comparison with traditional IP based vehicle communication. To address a few challenges of vehicular networks like high overhead and low communication efficiency, authors in [24] developed a novel design based on extending basic NDN features into VANETs. Although the design works well in the field of handling mobility, location based forwarding and data retrieval, there are no details about interest and data packet forwarding schemes.

There are some papers which indicate the research challenges of adapting CCN into VANETs. The authors in [25] check the feasibility of combining NDN into V2V and list few advantages this modified architecture brings. However, the authors also claim that interest forwarding schemes are the most important parameter which affects most of the performance outputs. Also, the content retrieval will be fast and smooth, if the forwarding scheme is efficient.

There are similar works [26, 27, 28] which have combined the NDN mode into VANET, to make vehicular communications more efficient and smooth. All these works have explained the concept, architecture, pros and challenges of the resultant architecture. There are no simulation results, customized forwarding mechanisms proposed to improve the efficiency of the network. To enhance the QoS in VANETs, the authors in [29] proposed a framework based on caching policies to organize the data in caching nodes, and they have named it as Vehicular Named Data Network (VENDNET). Considering the notion of clustering to reduce the overhead of the network, authors in [30] proposed a hierarchical architecture to disseminate the data based on NDN. Clustering of nodes helps in reducing the number of users connected to RSUs or Base Stations.

C. *NDN Architecture*

In NDN, the users are not concerned about the address of information source, rather emphasis is laid on the data. The packets requested by a user/consumer are named as ‘interest packets’ and the packets generated from the producer are referred as ‘data packets’.

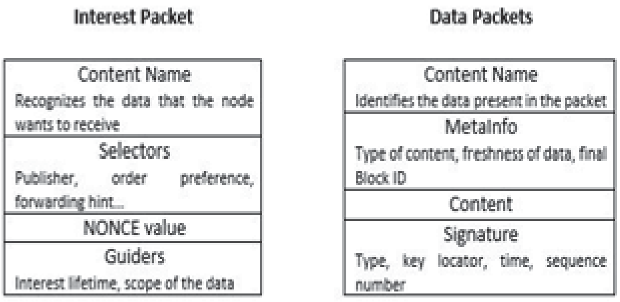

Fig. 1. Interest and Data packet formats in NDN

User broadcasts an interest packet with the content name to all the other users in the transmission range. This interest packet is forwarded by the neighbouring nodes until it receives the data packet from the original producer of the data or from any node which has cached the content with the same name. Every node in NDN architecture will maintain three important data components:

- Pending Interest Table (PIT): It is a forwarding table which saves the name of the content and keeps track of the interest packets received.
- Forwarding Information/Interface Base (FIB): It acts as a routing table which stores the prefixes of the names and the outgoing face/interface particulars. The interest packets are forwarded to the upstream through this information.
- Content Store (CS): It stores the data generated by the producer or stores the retrieved data from other users based on the demand in the network.

In case of content requirement, a node in NDN model transmits Interest packet which consists of name of the content, selector, NONCE value (4 bytes) and lifetime of the interest packet (set as 4s by default). Once the neighbouring nodes receive this Interest packet, the following citations will be initiated. Firstly, few PIT operations are performed. Although, literature suggest CS lookup as the first step, the modified architecture [31] skips this step, since it can help in reducing the delay and improve the general network performance as well. NONCE list is maintained in each node, which consists of previously satisfied Interest list or the discarded interest list. The incoming interest is checked against these lists. If there is no entry in the list, then the interest is categorized as valid and sent out for further processing. This helps in avoiding loopy of interest packets due to congestion and duplication of packets.

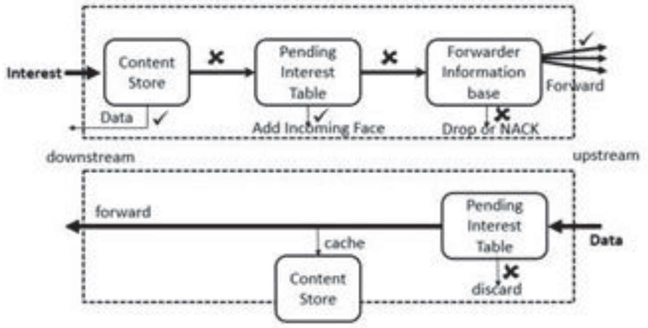

Fig. 2. NDN forwarding Model

In the second step, the interest packet is checked against the pending list present in the PIT. If there is an existing entry in the list, the packet is dropped, since the node has not found the route to reach the content and there is no point in forwarding it again. In absence of the entry in the PIT list, the content is searched in CS. Lastly, if the requested content is not found in CS it is called as ‘Content Store Miss’ and an entry in PIT is made along with content name and the incoming interface. At this step, it is clear that the node is neither the producer nor the provider of the requested data. Thus, the interest packets are forwarded to the upstream based on the FIB value.

There are a set of operations that NDN enabled node performs when a data packet is received. Firstly, the node searches in the pending list of the PIT, based on the entries, the data packet is sent to the respective Incoming interface (InFace). Next, the data can be cached in the node depending on the caching policy of the network. The time interval of storage and accessibility abides by the caching policy. Also, the name of the content and the NONCE value is recorded and the entries are removed from the pending list. Lastly, if there is no entry of the content in the pending list, the data packet is dropped.

D. *Challenges of VNDN*

The adaption of NDN into VANETs has shifted the communication paradigm to data centric from the conventional host-based system. Although this collaboration provides strong sense of addressing many challenges currently faced by vehicular networks, extending it is not a smooth process. There are numerous open issues to be addressed, among which the prominent ones are

- Routing Strategies: - An efficient routing mechanism is required to fulfil the QoS requirement, especially in highly mobile environment and dynamic topologies.
- Channel constraints: - Interest packets are broadcasted from the consumer nodes, and there are high chances of broadcast storm occurring. In order to accommodate mitigation mechanisms and ensure fault free transmission, bandwidth efficient and a robust channel is required.

- Naming Schemes: - Since the fundamental principle of NDN is retrieval of content based on the name of contents, it is important to have an apt mechanism to name the contents. There are multiple naming mechanisms of various characteristics proposed, however, there is no clarity on which mechanism is more suitable for VNs.
- Dynamic Network Topologies: - Highly mobile nodes and intermittent connectivity during large volume of data transfer, demands highly dynamic approaches.
- Interest Flooding and Data flooding: - Multiple nodes can generate interest and broadcast them. This can give rise to flooding of interest packets in the network and in return when the neighboring nodes of the producer reply with data packets, data flooding will occur.
- FIB, PIT and CS management: - All the responses forwarded or received must have entries in FIB and PIT. Numerous entries are noted, deleted or enquired in the process. In order to ensure QoS standards, effective strategies must be implemented. Similarly contents when passed through the nodes are cached in CS. Thus, effective caching strategy is required to make efficient utilization of memory and cater the data to requiring nodes.
- Security in NDVN: - Authentication and digital signature techniques can secure data but it adds considerable overhead as well. Other option is securing data through cryptographic mechanisms

III. Content Naming Schemes

Naming schemes play a critical role in content centric networks and affect the overall network performance. Naming schemes can reduce the length of FIB, make the routing and forwarding efficient and uniquely identify the data. However, they should not add to the overhead of the network and remain simple. The naming schemes in the content centric network and NDN can be classified into four groups: Hierarchical, Flat based, attribute based and hybrid methods.

Hierarchical naming schemes are majorly used in NDN architectures, few ICN applications use a simple self-satisfying flat based naming schemes. Attribute based naming schemes were initially used in routing for Content based and combined broadcast (CBCB) applications and some researchers focus on combining hierarchical, flat and attribute based techniques in a hybrid manner [32].

A. Challenges of naming schemes

In NDN, locating and routing depends on the naming of data. The naming schemes can be independent of the network, since the names are specific to applications and opaque to the network. They should be able to fetch the data transparently regardless of location. In addition, they should be globally unique, secure, location independent and human readable.

The names consist of delimiters and explicit components. Third version and sixth segment of a paper named 'ABC.pdf' published by ICPSPCT conference can have the name /ICPSPCT/paper/ABC.pdf/V3/S6. The '/' refers to the delimiters and they are not part of the name.

Hierarchical naming helps in scalability of routing via aggregation of clusters. Also, the readability aspect allows the user to remember the content names through which they can request the data directly. In order to name the content, the producer and the requester can use a deterministic algorithm based on the information available. However, the requester has the ability to retrieve the data using partial name also.

The readable and hierarchical characteristics of naming schemes can prove to be dangerous as well. In the hierarchical naming schemes, the user requests are visible and they are prone to name explosion problems. In addition, suffix hole problems can arise. Flat based naming schemes tend to increase the size of routing tables. They also reduce the aggregation of clusters which in turn affects the scalability. If the NDN content names are highly readable and meaningful, they attract the hackers, thus they become more sensitive. The challenge is to develop a naming scheme which produces meaningful, readable as well as secured content names.

B. Surevy of content naming schemes

The authors in [33], have developed a naming scheme based on geo-location. The name carries information like application, geo-location, data type, timestamp and NONCE value. This particular NONCE value identifies publisher of the data.

Another geo-location based method is proposed in [24], wherein a three level hierarchy is considered for naming the data. The first level contains the location of the destination of the node that requested for the data. The source of the data generated is included along with the next hop in the second level. The third level is used for scale-based aggregation, wherein the scale can be street, city or district.

A two dimensional geo-location based approach is proposed in [34]. Several bits are used to encode the current location in dimension pair (a, b). Similar such bit pairs generated (a[i], b[i]) from low to high bits. This two-dimensional pair is converted to one-dimension through canter pairing function and is use as the naming component.

Hierarchical naming based on popularity of the content and shareable level is proposed in [35]. The naming scheme has three fields: category, service and additional information. The category field has entries depending on the popularity level and points given based on the shareable levels. In case of non-shareable popular data, least points are allocated. The last category is reserved for unpopular data.

Multimedia based hybrid naming scheme is proposed in [36]. It consists of three segments. The first segment is a routable prefix utilized for data dissemination. The middle segment called as flat data identifier is used to fasten the process of caching retrieval. The last segment of primary attribute labels ensures optimal Quality of Experience (QoE). Flat naming methods and hierarchical architecture is combined in this hybrid approach to improve the scalability and add more efficiency to the conventional naming schemes.

The authors in [37] propose a secure naming scheme. The data is kept confidential and can only be accessed by authorized parties. It is a hybrid scheme which combines

TABLE I. SUMMARY OF CONTENT NAMING SCHMES

Name	Characteristics	Type	Comments
Data Naming in Vehicle-to-Vehicle Communications [33]	Timestamp and geo-location based	Hierarchical	Strawman based naming technique is used to disseminate traffic information
Novel Vehicular Information Network Architecture Based on Named Data Networking [24]	Location-based	Hierarchical	The proposed mechanism supports both push based and pull based communication
A Naming Scheme to Represent Geographic Areas in NDN [34]	Geo-location based	Hierarchical	Improves in-network caching and maps bi-dimensional geographic locations into uni-dimensional names
Scalable VANET Content Routing Using Hierarchical Bloom Filters [35]	Popularity awareness based	Hierarchical	Less response time and traffic, however, the mechanism has more overhead
Social Cooperation for Information-Centric Multimedia Streaming in Highway VANETs [36]	Enhancement of QoE	Hybrid	Hybrid naming scheme enhances multimedia transmission in highway traffic scenario
A Privacy-aware Naming Scheme in Named Data Networking [37]	Privacy Aware Naming scheme	Hybrid	Hierarchical component works as a prefix and flat component is data.
Enhancing content-centric networking for vehicular Environments [31]	Counter - based	Hierarchical	Some more features can be added in Option field, to enhance content delivery.

both hierarchical and flat based methods. The prefix for the data has hierarchical characteristics and the data follows flat based characteristics. The length of the hierarchical names are reduced, since it is restricted to only prefix of the names, this in turn reduces the routing table entries. The data component is encrypted to make the naming scheme more secure.

The authors in [31] propose a hierarchical naming scheme, wherein a large NONCE value is selected to avoid duplication of packets. A pair of Content ID (CID) and Provider ID (PID) is used to distinguish different content and different chunks. The forwarding scheme can be enhanced by decoding the provider information which contains PID and location. Addition fields can be added in the Option field to enhance content delivery.

IV. Conlcusion

NDN has played a pivotal role in realization of information centric networks. The paper discusses the literature related to the paradigm shift from host centric to content centric networks, NDN architecture, packet formats and research challenges of vehicle networks. A brief history of NDN, working model and its applications are highlighted. Since VNDN is a relatively new domain, major challenges that needs to be addressed have been summarized. The paper mainly focusses on content naming schemes used, their pros and cons and the methodologies implied. The content forwarding strategies have been categorized into six groups namely, hop and timer, popularity, geo-location, SDN and vehicle cloud, heterogeneous and infrastructure and unicast schemes. Various content caching policies applied in VNDN, the simulator tools used and drawbacks have been discussed. Through the survey, it is evident that there is requirement of efficient and intelligent forwarding mechanisms in NDN. Commercialization of NDN based VANET is still under speculation due to various issues observed in the survey and the paper encourages researchers to solve the open challenges posed by NDN.

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