Chapter 15
Software Defined Virtual Clustering-Based Content Distribution Mechanism in VNDN

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Abstract Vehicular named data networking is supporting various kinds of content-oriented applications. The inherent feature of in-network caching in Named Data Networks helps in an efficient delivery of the content and provides a better communication in vehicular network. However, the vehicles are moving with varying speed, due to which the process of content distribution becomes challenging. Furthermore, these problems can be overcome by integrating NDN with vehicular ad-hoc network. To provide support in this direction, we propose a Software Defined Virtual Clustering Scheme for Vehicular Named Data Networks, which provide a flexible environment for accessing any type of content to a moving vehicle at its present location. In the proposed model, various virtual clusters are formed based on different content type and all these clusters are controlled by a central SDN Controller. Content distribution mechanism has been developed for inter cluster communication to provide nonnative cluster information to the consumer. The simulation results show that most of the vehicles can acquire the requested content and can significantly improves the performance of the network.

Keywords Vehicular network · Named data network · Virtual clusters · Software defined networks · SDN controller · Content distribution

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15.1 Introduction

These days the prime aim of smart cities is to change the life of people by excelling in numerous areas such as safe environment, stability and economic growth. There are several factors like development of technologies, intelligent transportation and motivation to wards ease in an individual's life style which are the prime responsible factors for this conventional growth. Intelligent Transportation System (ITS) is one of the key parameters in the growth of these cities. On the other hand, Vehicle ad-hoc Networks (VANETs) is showing its progress and playing a vital role in ITS and supporting various needs of smart cities in terms of faster data delivery and communication. There as on behind this achievement is integration of traditional VANETs with various technologies such as Software Defined Networks (SDN) [1], Internet of Things (IOT) [2], Fog Computing [3], Edge Computing [4] etc. The integration of VANETs with SDN has built a new communication system which has resulted in heterogeneous, programmable and large-scale networking. The integration of these two technologies is named as Software Defined Vehicular Networks (SDVN) [5, 6]. SDVN is a software enable networking mechanism in which the whole infrastructure is divided into layered architecture with centralized controller. This layered architecture comprises of application, control and data layer. This architecture provides a paradigm that differentiates the control plane from the data plane. The data plane includes data forwarding elements such as routers and switches. In the control plane of SDN, the controller is placed to manage and handle the entire network. Open-flow controller work on the control layer of SDVN. This provides a broader vision of the network which ultimately helps in the managing the tasks. The application and data layer are served by the central layer by using the north and south bound interfaces. On the application layer different applications and policies are designed for data communication. In SDVNs, delivery model is based on IP, where point-to-point connection takes place during data transmission which may leads to issues of unstable connection between vehicles during high mobility [5]. To overcome this issue an alternative type of network architecture came up as a solution which is known as Information Centric Networks [7]. Among the various types of Content Centric Network, the most well-managed network architecture chosen is called Named Data Networks (NDN) [8]. NDN focuses on content distribution by utilizing the content names rather than addresses. It provides the requested content from any of the nearby node regardless of the location of the producer. NDN's communication process includes two types of packets for communication such as Interest packets (IP) and Data Packets (DP) [9]. The named consumer node sends an Interest to the network and the named producer revert with the requested Data as shown in Fig. 15.1. Each node of NDN maintains three data structures such as Content Store (CS), Pending Interest Table (PIT) and Forwarding Information Base (FIB). The forwarding daemon of NDN includes the Interest forwarding process. A consumer sends an Interest in the network. When a node receives the same, it performs a looks up function on the data in its CS. On look up hit, the Data is sent back to the consumer. In case of a miss, the Interest is checked against the PIT

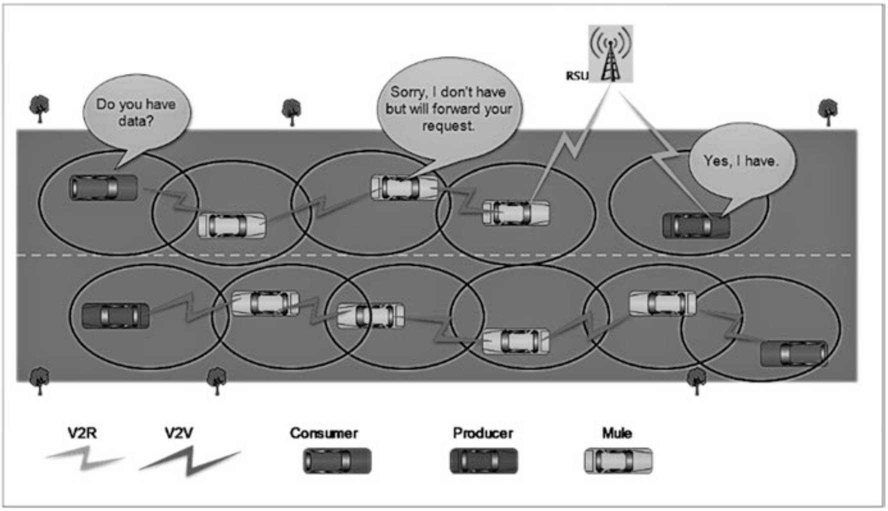

Fig. 15.1 NDN communication architecture

entries. On encountering an entry in PIT, the Interest is discarded. In case of a look up miss in PIT, the entry of the Interest is made in PIT and further forward it to the next hop by looking at the FIB. In the delivery phase, whenever a node encounters Data it checks whether an entry with the same name exists in PIT. In case the match is not found, the packet is discarded and if the match exists, the node multicasts the DP to all incoming interfaces and the PIT entry is discarded after satisfying the request [10]. The same communication process can be a beneficial to ben turn in the field of vehicular networks. Thus, a lot of research is gaining its Interest in vehicular named data networking [11] which makes NDN as a communication architecture for VANETs. This combination of SDVN with NDN provides a better network management [12], avoidance of transmission interference, reduced delay and supports cooperative data dissemination.

15.1.1 Data Dissemination in SDV

The data dissemination in SDVN supported NDN networks can be performed efficiently with the help of clustering [13–15]. These clusters can be formed based on various parameters such as relative mobility patterns of vehicles, trajectories, locations, speed and a search for a specific Interest. Through clustering long term connections can be created within vehicle which would help in fast delivering the content and also reduce number of re-transmissions [16]. In our proposed mechanism, for an efficient content distribution caused by high mobility vehicles, NDN supported software defined virtual clustering-based content distribution (SD-VCCD) mechanism in VANETs is proposed. Here, virtual cluster are created based on the particular request generated by the moving vehicles, which would contain the information of those vehicles only, who will be the part of communication for that particular Interest. These clusters will be managed by the centralized SDN controller.

15.1.2 Contributions

The main contribution of the work focus on the following:

(a) To identify the producer node, creation of chain like structure for a particular request by broadcasting IP request.
(b) A virtual cluster-based technique is used to divide the vehicles into different clusters. The formation of clusters is done on the basis of particular Interest packet request.
(c) In the designed scheme, the SDN act as a static cluster head which further manages all the clusters and communication occur between vehicles efficiently.
(d) According to experiment results, the scheme helps in improving the data management and transmission for high-speed vehicles.

15.1.3 Chapter Organization

Rest of this chapter is organized as follows. Section 15.2 describes related work and Sect. 15.3 presents the proposed system mode land network architecture of SD-VCCD for vehicular NDN. Section 15.4 states the proposed work while Sect. 15.5 presents an analysis of the results, followed by the conclusion of the presented scheme.

15.2 Literature Review

This article deals with the content distribution by using SDN with V-NDN to achieve effective distribution of content via virtual clustering in vehicular network. Therefore, this section contains are view of important work related to content distribution in NDN, V-NDN, SDN and clustering in vehicular networks.

15.2.1 Named Data Networking

Jacobson et al. [17] proposed a blueprint of NDN architecture along with highlighting the importance of retrieval of content by their names for a generic CCN. The blueprint focused on different aspects related to content-oriented data forwarding. Zhang et al. [8] extended the generic CCN architecture and conceptualized NDN as an alternative network architecture and implemented one of the preliminary versions of Information Centric Network. Zhang et al. [18] described the vision towards the new architecture based on Content Centric Networking called Named Data Networking. The main components along with the various operations has been briefed inside. The design of NDN along with the development status and various research challenges are also presented. Yi et al. [19] proposed the design of NDN's adaptive forwarding and explained various benefits derived from the forwarding process. The design focused on the effective utilization of Data and Interest packets so as to achieve high performance and resilience in an NDN network.

15.2.2 Vehicular Named Data Networking

Wang et al. [20] proposed an IP-based vehicular Content-Centric networking framework by focusing on addressing technique. The framework used address-Centric unicast instead of the Content-Centric broadcast for effective communication. The proposed framework achieves a better content acquisition, success rate and reduce the cost for the same. Duarte et al. [21] proposed a distributed framework for Vehicular Named Data Networking (V-NDN) communications called MobiVNDN. Its main focus was to reduce the effect of communication performance overheads caused by mobility and wireless communications in V-NDN. It also addressed several other issues including broadcast storm, redundancy, reverse path partitioning, network partitions, and content source mobility.

Araujo et al. [22] presented a test bed for evaluating various applications of IT Sin V-NDN. The proposed test bed allows bidirectional communication and integrates the NDN stack as well as network forwarding daemon code. The test bed integrates key components such as set of codes, models, functionalities, and technologies to improve functionality of V-NDN. Grassi et al. [23] proposed a network architecture for V-NDN and applied designed to address challenges present in traditional VANETs. The architecture uses NDN based naming scheme that decouples the communication process, so that data can be efficiently retrieved from the any one of the nearby interfaces. This architecture increases the performance of the system by exploiting the key parameters of V-NDN.

15.2.3 Software Defined Network

Alowish et al. [24] proposed VANET architecture with two different technologies such as SDN and NDN. The NDN is used to resolve the issues related to IP addressing and SDN is used for the global view of the network. A policy-based bi-fold classifier is used for segregation of Interest packets for effective data delivery. This architecture is evaluated in terms of specific Interest packet parameters such as Interest satisfaction rate, Interest satisfaction delay, forwarder Interest packets, average hop count, and scalability in software defined networking-controlled V-NDN. Ahmed et al. [25] proposed an architecture which combines the functionalities of SDN and vehicular networks for the retrieval of required content via NDN. Various components of proposed architecture such as SDN controller, Caching, Content Naming, Intelligent Forwarding, Push-Based Forwarding, Intrinsic Data Security, Congestion Control, Topology Indicator, Content prefix manager and State Information are discussed in detail. The SDN and NDN enabled Vehicular Networks along with their similarities are also analyzed. Arslan et al. [26] proposed a broadcast storm avoidance mechanism (BSAM) for SDN and NDN-based VANET. All the IPs and DPs are cached at the controller site. However, caching huge number of packets in the controller leads to delay.

15.2.4 Clustering in V-NDN

Wang et al. [27] proposed a novel V-NDN framework to increase the stability of backbone topology through a cluster-chain scheme by fulfilling consumers request by following uni-cast mode to acquire data from the nearest provider. The framework is evaluated on the basis of various parameters such as speed, transmission radius and rounds. A reduced acquisition delay, success rate of data retrieval along with the low network cost is achieved. Fan et al. [28] proposed a solution for the broadcast storm by a broadcast storm mitigation strategy based on hierarchical hybrid network architecture integrated with distributed data named cluster. The scheme introduced a real-time route update algorithm, which updates the local interface node on the basis of named set of data received from the vehicles. The local interface node further updates the data at the local cluster and FIB. The strategy aims to mitigate the effect of broadcast storm thereby improving the communication efficiency among the vehicles. Hou et al. [29] proposed a DP Back-haul Prediction Method based on clustering. The method focused on the problem of reverse path breakage for DPs caused by high mobility of vehicles. A routing mechanism based on Back-haul prediction was produced. This method establishes cluster routing based on the structure of clusters and further the target road-side unit is predicted which improves the inter-cluster performance. The scheme achieved a reduced average delay and packet loss ratio in the vehicle-to-infrastructure communication in urban scenarios. Ardakani et al. [30] proposed a Cluster-based routing protocol called CNN. It uses the hamming distance technique to form clusters and the network transmissions are handled based on named data networking. Hybrid communication along with Dedicated Short-Range Communication has been used for intra-cluster link establishment and inter-cluster transmissions. The protocol shows an improvement in various parameters such as, average end-to-end delay, path length, data delivery ratio, and total transmitted traffic. Siddiqa et al. [31] proposed a vehicular-Content Centric network which adopts in- network caching to satisfy the requests. Further, to address the problem of broadcast storm a multi-head nomination clustering scheme was proposed. The scheme forwards the hello packet header to access the information about the vehicle from the cluster. A proposed cluster information table (CIT) is used to store the information regarding the nominated heads. The road-side unit nominates the new head on the basis of CIT entries which finally eliminating the broadcasting storm effect on disruptive communication links gives vehicle to focus on the problem of broadcast storm. The scheme helped in increasing the successful communication rate, decreases the communication delay, and ensures a high cache success ratio on an increasing number of vehicles. Sampath et al. [32] proposed a position-based adaptive clustering model to solve the issues regarding frequent cluster formation. The cluster formation was performed using the trajectory as the main parameter. The model provides an improvement in various parameters such as packet delivery ratio, mean delay, cache hit rate and mean hop distance. Huang et al. [33] proposed cluster-based cooperative caching approach with mobility prediction in V-NDN. The cluster formation was done on the basis of mobility pattern of vehicles by using the concept of mobility predictors. The approach classifies the cached data content into most and least popular data based on request frequency for increasing the cache resource utilization. A cache placement and transmission schemes is also proposed. This approach provides a stable and are liable delivery of data among the vehicles and simultaneously increasing the performance of the system. The above discussed schemes and approaches are use full for various types of scenarios. These schemes include clustering to increase the performance of the network. However, there is still a gap for efficient communication within a high-speed vehicular network. The high-speed networks need a better scheme as the high mobility causes the break in the connection, which will result in packet loss and ultimately decreases the efficiency of the network.

To evaluate the effectiveness of above protocols a comparative analysis of the reviewed NDN based schemes has also been done. Table 15.1 depicts this analysis in terms of clustering techniques used for content distribution with respect to named data networks.

Table 15.1 Comparative evaluation of NDN based clustering schemes

	CH selection	Evaluation parameters			NDN Characteristics		Scenario		Communication mode	
Paper Ref.15		Packet loss ratio	Delay	Cache hit ratio	Routing	Caching	Urban	Highway	Uni-cast	Broadcast
[20]	NA	✖	✓	✓	✓	✖	✓	✓	✖	✓
[22]	NA	✓	✓	✓	✓	✖	✓	✖	✖	✓
[23]	NA	✓	✖	✓	✓	✓	✖	✓	✖	✓
[27]	Link duration time	✖	✓	✖	✓	✖	✓	✖	✓	✖
[28]	NA	✓	✖	✖	✖	✓	✓	✖	✖	✓
[29]	Middle node	✓	✓	✖	✓	✓	✓	✖	✖	✓
[30]	Maximum connectivity	✖	✓	✖	✓	✖	✓	✖	✓	✖
[31]	Cluster information table	✖	✓	✓	✓	✓	✖	✓	✖	✓
[32]	Relative velocity	✓	✓	✓	✖	✓	✖	✓	✖	✓
[33]	Relative velocity	✖	✓	✓	✖	✓	✓	✖	✖	✓

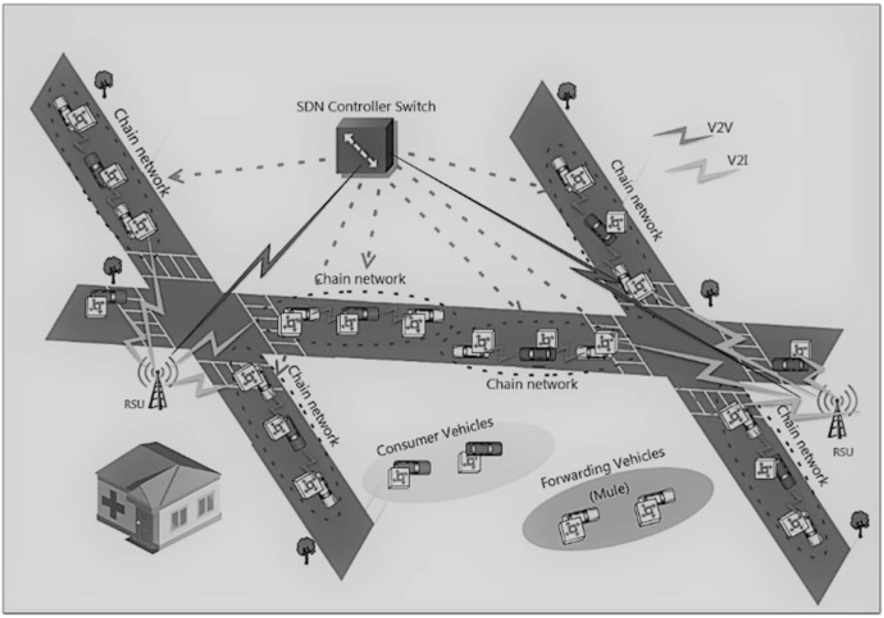

Fig. 15.2 Virtual cluster based chain structure for VNDN

15.3 System Model

The aim of the proposed system model is to deliver the content from the producer to the consumer in an efficient way. To achieve the desired level of communication a virtual cluster-based content distribution scheme is designed. In the proposed scheme the whole infrastructure is supervised by SDN controller as shown in Fig. 15.2. In this figure, the content distribution between the vehicles is done by utilizing NDN network forwarding daemon strategy. In this type of network, the request for content is generated by the vehicle and the generated request is fulfilled by any of the nearby vehicle irrespective of the producer of the content. The generated content can be bifurcated and stored in the virtual clusters. These clusters are formed on the basis of types of content such as safety alerts, entertainment and education. In this individual virtual clusters are created for each content type. These virtual clusters are further connected and controlled by the SDN controller. In case the requested content is not available with the neighboring vehicle, the Interest packet request will be broadcast to the next and previous hop until the producer node is not found. The tasks performed by each component of the network are discussed below:

- V-NDN: The whole vehicular network is observed under NDN. In this each vehicle which is requesting for data will be named as consumer's node and it will raise an Interest packet. The vehicle who will provide the Data to fulfill the requirement of consumer node will be known as producer node.
- FIB: This is at able which is created at every node, the main components of FIB are name prefix and next hop. FIB can be filled in two ways self-learning and

routing protocol. It helps in breaking Interest looping and can freely use any/all paths. In our proposed scenario, we are creating centralized FIB table at SDN switch to support centralized communication. Due to this centralized FIB, it would be easy to find the consumer mobile node.

- PIT: It is also formed at every node. Each entry in the PIT comprises of Interest name, incoming interfaces and outgoing interfaces sending time. Centralized PIT will also be created at SDN *switch* SIDE. The role of this PIT is once the consumer node that will receive the data by using the PIT from the centralized table it would be updated one a CH vehicle that were the part of the FIB table to break the connection.
- CS: As we know each vehicle in our proposed network is supporting NDN so now each vehicle can perform caching in its content store to check the requested data by the consumer node whether that data is available or not in its content store.
- Virtual Clusters: Theses clusters are used over the vehicles that form a chain. There will be separate chain of vehicles for a particular request. Vehicle which are the part of a particular request will become part of virtual cluster. Virtual cluster will be updated periodically because each vehicle would add new vehicle for the searching of data.
- SDN- The role of SDN is to manage PIT and FIB tables centrally as its core functionality. It will work as supervisor of whole underlying network as it will control and manage the all activities taking place within the vehicles. Virtual cluster creation and updating, link establishment and dissolving, all these activities will be created and implemented by the centralized controller only.

As SDN works on layer architecture, all the above components are logically designed on the different layers of SDN as shown in Fig. 15.2. Here, VNDN will be on the physical layer and each VNDN would have their own CS, PIT and FIB table. In the control layer, there will be centralized SDN controller which will control the whole network. In the application layer each application such as virtual cluster creation, content distribution etc. will be designed. In the next section, the working scenario of proposed scenario with respect to network model is discussed in detail.

15.4 Network Model

In proposed network model, we are assuming each vehicle on the road is moving bidirectionally and supporting NDN. Therefore, each vehicle would have their own cache for content storage. These vehicles would also have FIB and PIT for storing data transmission records. Here, first the Interest packet request will be broadcast by consumer node and after that the request will be forwarded to the next node from hop-to-hop only in forward and backward direction until the producer is not found. This will create the one-to-one links between different nodes that would help in traversing of data from producer to consumer by using V2V communication only. To support this vehicular communication various policies are designed and implemented on the SDN application plane. By utilizing these policies, virtual cluster of the vehicles for each type of content is generated for a particular request and which

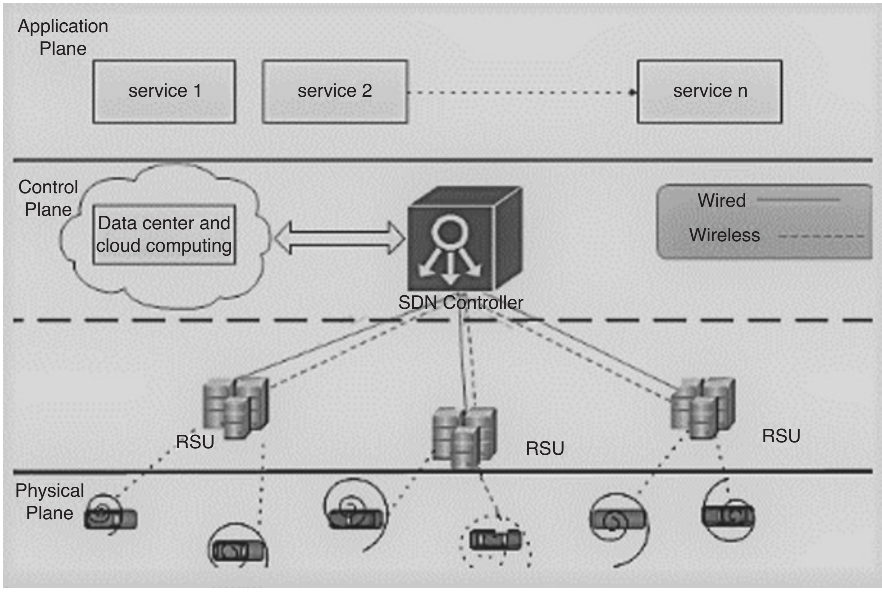

Fig. 15.3 Logical distribution of various components on SDVN layers

is updated periodically. The whole working scenario of proposed network model is classified into some steps. The first step is to create nomenclature for the request message and then the other steps involve Interest packet generation by the consumer node, nomenclature of message, updating of FIB table, virtual cluster creation and update, update of PIT table. All these steps are discussed in details as follows:

Interest packet generation: In this any V-NDN who requires data can generate an Interest Packet (IP) request and broadcast it to all neighboring vehicles as shown in Fig. 15.3. In this figure IP request is generated by the consumer node and it has been broadcast to all neighboring vehicles. Before broadcast nomenclature of the IP will be done which is described in next step.

Nomenclature Scheme: This nomenclature scheme is one of the policies which is designed at the application plane of SDN. By utilizing this scheme each IP packet would be given a unique name. This proposed naming scheme is used to name the data as well the vehicles. The data naming follows this format: /*<area>*/*<location>* /<V_{id}>/*<datatype>*. In this format, area explains the area from where the vehicle belongs to, location depicts the data at the origin, V_{id} is the reference Id of vehicle and lastly, domain specifies the category to which the type of data belongs to. The parameter area will be selected through the designed policy at the application layer of SDN. The parameter location can be calculated on the basis of the x and y coordinates. Let x and y are the coordinates that shows the location that is required to add in the naming component. Let c_i be a pairing function on which both the parts of the coordinates agreed upon. The coordinates are represented in decimal form of sequence of digits. These are aligned on the decimal points, and the leading zeroes are added until the same number of digits are achieved. If the decimal points are ignored, the resulting sequences will be in the form x_1, x_2, x_3, …, and y_1, y_2, y_3, ..., y_n. Finally, $\forall c_i = 1, , n$, calculate:

$$f(x_1,y_1) = \frac{1}{2}(x_1 + y_1)(x_1 + y_1 + 1) + y_1 \tag{15.1}$$

$$c_i = f(x_i,y_i) \tag{15.2}$$

Every c_i becomes a separate NDN name component called location. The location can be added separately to the regular naming of the data. Here V_{id} denoted ask will be vehicle unique ID which is calculated based on the parameters such as 48 bit vehicle's OBU ID (OBU_{id}) and vehicle number (V_{Num}). Blockwise ⊕ operation is performed to generate k bitV_{id} of the vehicle as shown in below equation.

$$k = OBU_{id} \oplus V_{Num} \tag{15.3}$$

Lastly, the parameter data type can be classified on the basis of the domains to which the data belong to. The whole procedure of nomenclature is represented in the below algorithm. Suppose area in which IP is generated is Toronto and the type the data request is educational data. So, after implementing all the steps the final nomenclature of each IP will be represented as "/toronto/c_1/k/edu/".

Updating of FIB table: After broadcasting IP requests consumer node will update its FIB table with the ids of the vehicles to whom it had sent the IP request. Then the vehicles who has received the request from consumer node will check their content storage whether that data is available or not. If that data is not available with them then they will send the same request to its next hope only and this process will be continued until producer node is not found and would create a chain like structure.

Algorithm 15.1: Interest Packet Nomenclature

Input: Vehicle Coordinates ($vx_,$)**, OBU Id (OBU***id***),**
*vehicle numbe***(V***Num***)**
Output: Nomenclature of IP
1: Begin
2: TransmitIP_{REQ}Message
3: Initiate Nomenclature Process
4: **if** (Unsuccessful) **then**
5: return-1;
6: **else**
7: return Vehicle area
8: $f(x_1,y_1) = \frac{1}{2}(x_1 + y_1)(x_1 + y_1 + 1) + y_1$
9: $c_i = (x_i, y_i)$
10: return c_i;
11: $k = OBU_{id} \oplus V_{Num}$
12: return $V_{ID}=k$;
13: return content type
14: **end if**
15: End

Virtual cluster creation: There would be assumed as on centralized FIB at the SDN side which would have entry of each vehicle which is part of the communication chain. The collection of these vehicles will be named as virtual cluster and each vehicle entry for that particular IP request will considered as cluster member. These cluster a managed by the SDN controller each new vehicle enter into the chain will become a part of the virtual cluster. Virtual cluster will be updated periodically to check the active chain members.

Updating of PIT table: PIT table is also managed by each vehicle. PIT entry in the table of cluster member will be pending until the producer is not found. Once the producer is found data will be move back to consumer node according to FIB table and PIT will also be updated for a particular IP request. For each pending entry P will be updated in the PIT table.

Data Transmission Stage: Once the producer node is found during chain creation process then data transmission will take place from producer to consumer. For this only those vehicles will be the part of communication whose entry is available is the virtual cluster. By utilizing those vehicular ids, through backtracking data will be transmitted to the consumer node. This procedure for backtracking will take place by using FIB table of each vehicle. After transmitting data each vehicle will update its PIT table also and once PIT status will be updated as successful that vehicle will be removed from virtual cluster. The process of data transmission from producer to consumer is shown in algorithm 15.2. Once the consumer is removed from the virtual cluster link dissolving process will take place which is describe in the next step.

Chain disconnection: Once the consumer has received the data it will be removed from the centralized FIB then PIT entry will be multicast to all vehicles who are the part of virtual cluster. After this all connection of the vehicles will be dissolved. The whole procedure for this V2V communication using NDN is described in algorithm 15.3.

Algorithm 15.2: Data Transmission from Producer to Consumer

Input: $Producer_{id}$
Output: Data Transmission Status
1:Begin
2: **if** (Producer Found==True)**then**
3: **while**(Consumer's PIT entry!=Successful)**do**
4: $backtrack V_{id} from FIB table$
5: transmit data
6: update PIT table
7: update virtual cluster
8: $update\ Producer_{id}=V_{id}$
9: **end while**
10: **else**
11: Chain Creation Process Continues
12: **end if**
13: End

Algorithm 15.3: Chain Rule Procedure

Input: g_{Code}, V_{id}
Output: Status Flag

```
Begin
Check Interest Packet Status
if Interest packet Status==True then
    IP Nomenclature
    while (Producer Status! = True) do
        broadcast IP request
        for each road segment do
            select chain leaf members
            Add leaf member to chain
            update chain status in virtual cluster
            for (each leaf node v=1 to N) do Check Content Store
                if (Content status==True) then
                    transmit data
                else
                    Update FIB table
                    Update PIT table
                    Update virtual cluster
                end if
            end for
        end for
    end while
End
```

15.5 Implementation and Result

To analyze the performance of SD-VCCD an urban roadside scenario has been considered, where the vehicles move along the different road segments. To implement this generated scenario ns-3 version 3.30.1 [34], with the ndnSIM [35] module version 2.0, are used which performs basic features of NDN. Ubuntu 18.04 has been used for testing and installing the entire environment. For incorporating the structure of VNDN into the simulated model, CS, PIT and FIB components of NDN as well as mobility has been considered. Table 15.2 shows various parameters along with description values which have been used for simulation. The maximum number of vehicular nodes used is 350 where each node is capable of acting as either a producer or a consumer. The Best route routing method has been used for creating the urban road side scenario in which the packets are directed by using the chaining scheme created in SD-VCCD. The number of Interest packets generated per second ranges from 10 to 35 packets, and the average packet size considered is 1024.

Table 15.2 Simulation parameters

Symbol name	Description
Parameter	Description value
Maximum number of nodes	350
Number of consumers nodes	350
Number of producers nodes	350
Routing method	Best route
Range of interest packets generated per second	10–35
Payload for data	1024
Vehicle speed	0–60 Km/h
Range of chaining cardinality	20–200

For simulating SD-VCCD, the term chaining carnality which defines the average number of vehicular within a chain has been considered. The value of chaining cardinality ranges between 20 and 200. The implemented urban roadside scenario works for Interest packets based on real-time content distribution between producers and consumer nodes. This scenario provides a logical representation of vehicles in NDN environment. To initiate content distribution, some consumer node raises an Interest over the network. As soon as the Interest packet arrives at the first installed NDN router in the network, the content is checked in its CS. In case the data is available in the CS, it is immediately forwarded back to the consumer node, otherwise PI and further FIB will be checked respectively. The raised Interest is forwarded in uni-cast mode within the chain. The chaining process generates a virtual cluster which is further attached to SDN controller and helps in providing the data thereby minimizing the look-up time. The performance of SD-VCCD is evaluated on basis of parameters such as Normalized Transmission Overhead and Throughput. The performance of proposed scheme is also compared on the basis of Average Delay and Interest Satisfaction Ratio with existing broadcast schemes such as Conventional VNDN (C-VNDN) and Distance Assisted Data Dissemination (DASB) [36] by considering two different simulation scenarios.

Figure 15.4 represents a static simulation scenario where a collection of vehicles tend to interact with each other directly. The scenario comprises of a partial snapshot representing vehicular nodes acting as producers and consumers.

Figure 15.5 shows the dynamic simulation scenario used for the evaluation of proposed scheme and represents a chaining process among the vehicular nodes, linking the producer with the consumer in a grid pattern.

Figure 15.6 shows the performance of the SD-VCCD in terms of Normalized Transmission Overhead. The figure depicts that as the Chaining Cardinality increases the Network Transmission Overhead decreases. The analysis shows that an increase in number of nodes results in decrease Network Transmission Overhead because the Interests will be satisfied by the increased range of chain. It shows that SD-VCCD has the least normalized transmission overhead, as the Interest has been satisfied by centralized SDN controller.

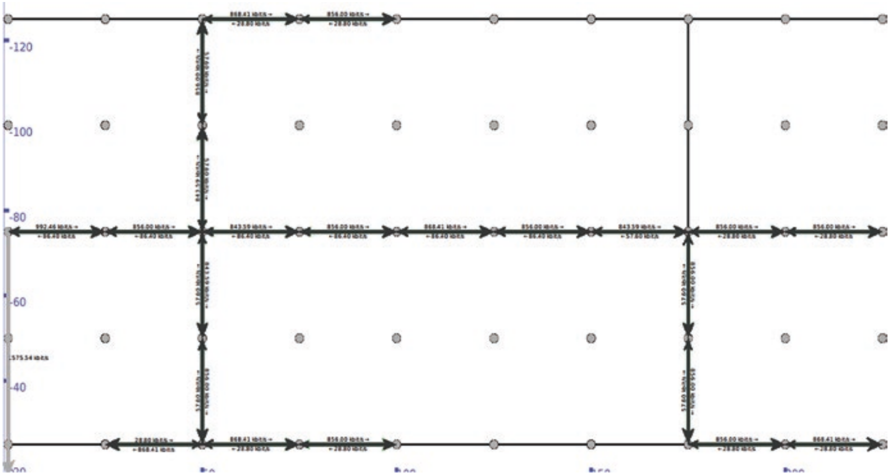

Fig. 15.4 Static scenario

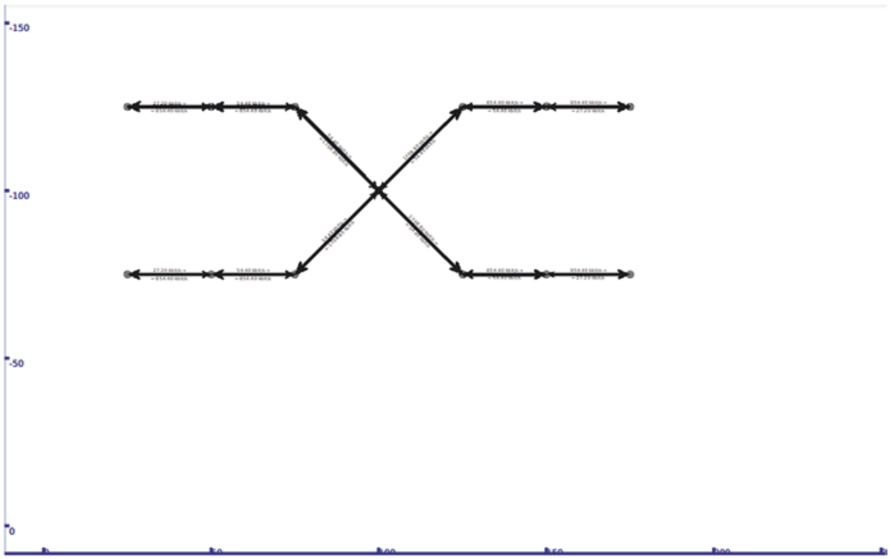

Fig. 15.5 Dynamic scenario

Figure 15.7 shows the Throughput for various number of nodes with respect to Simulation time. The behavior of the network shows that initially Throughput is at lower level but as the Simulation progresses, it increases gradually and reaches its saturation value. As the figure shows, increasing the number of nodes results in higher throughput value in SD-VCCD. This is due to the fact that the integrated SDN controller provides higher values for successful message delivery thereby improving the network throughput. To validate the performance of SD-VCCD, a comparative analysis has been performed with C-VNDN and DASB.

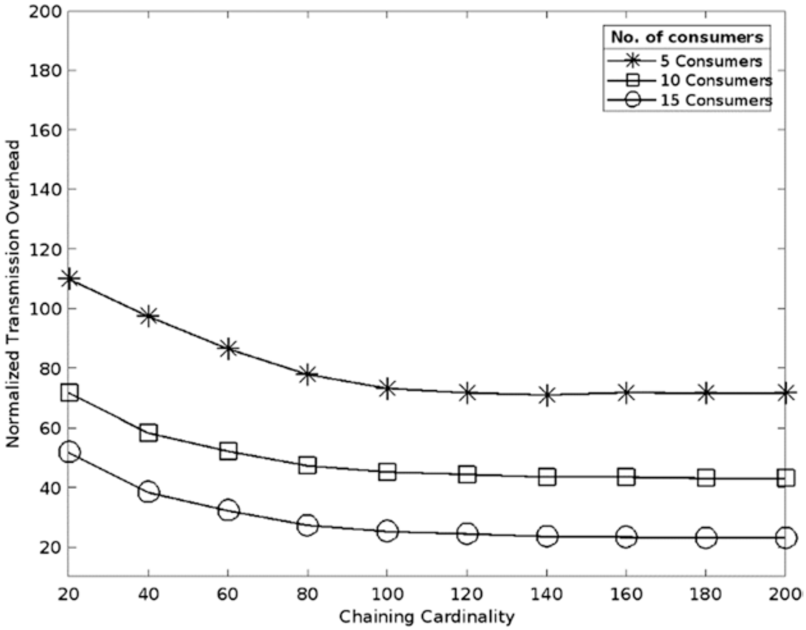

Fig. 15.6 Normalized transmission overhead vs Chaining cardinality

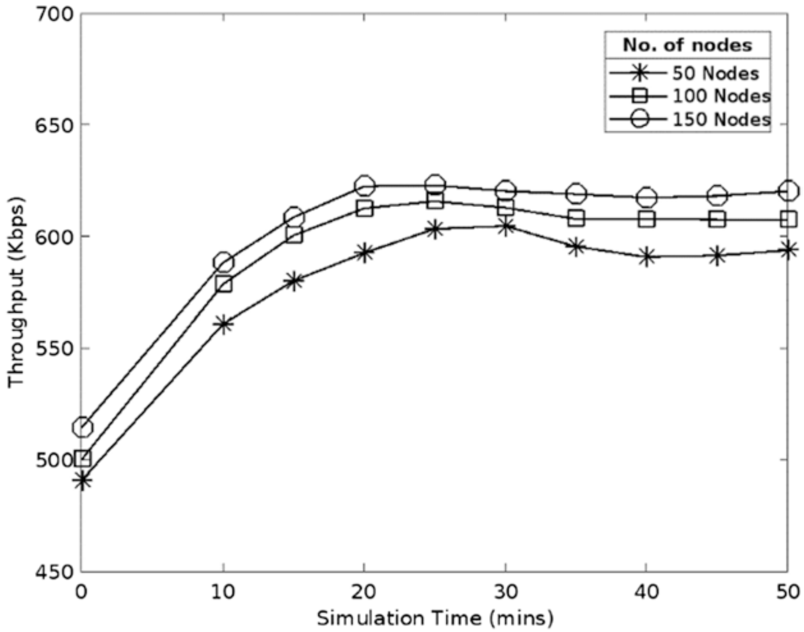

Fig. 15.7 Throughput (Kbps) vs Simulation time (mins)

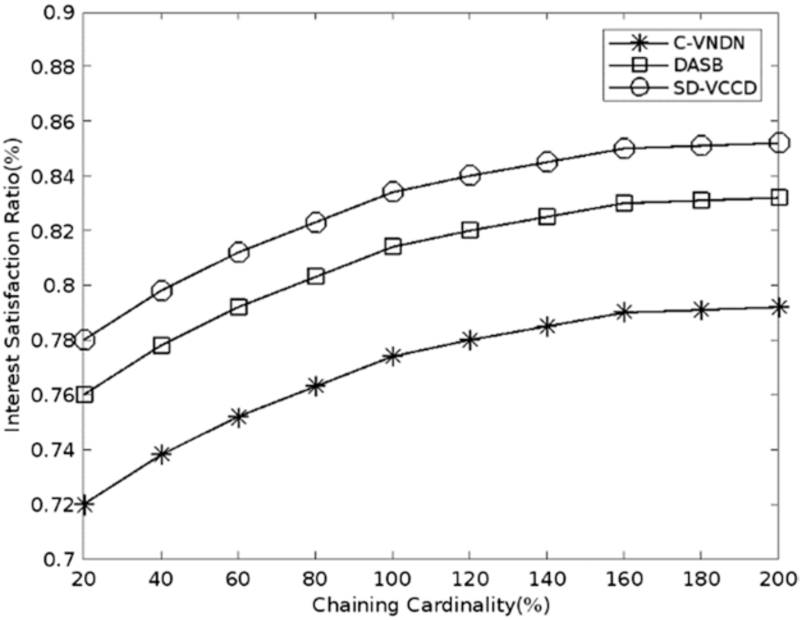

Fig. 15.8 Interest satisfaction ratio (%) vs Chaining cardinality (%)

Figure 15.8 depicts the performance of Interest Satisfaction Ratio of the above three schemes. It shows that average percentage of data received in response to the Interest is gradually increasing as the number of vehicles increases. The Interest Satisfaction Ratio of C-VNDN is lower than DASB and the SD-VCCD. The proposed scheme achieves the highest Interest Satisfaction Ratio as the Interest will be initially satisfied by all the neighboring vehicles with the help of NDN and in case the Interest is not present nearby it can be satisfied by the centralized SDN controller by forwarding it to the producer, which ultimately fits in with expectation.

Figure 15.9 shows the variation in average delay in terms of number of vehicles on the road. The value of average delay exhibits minor variations as the number of vehicles are increased. Initially the delay is a bit higher but with the increase in number of vehicles it decreases slightly ultimately attaining a constant value. The value of average delay is lower in case of SD-VCCD as compared to C-VNDN and DASB. This is due to the use of NDN based chaining structure resulting in the first nearby vehicle satisfying the Interest, resulting in lesser values of average delay of SD-VCCD. Thus, the obtained simulation results show that implementation of proposed chaining based virtual cluster in NDN results in effective content distribution of messages among vehicles travelling on an urban road. The use of high-capacity DPs also types of data within vehicles moving in the smart city.

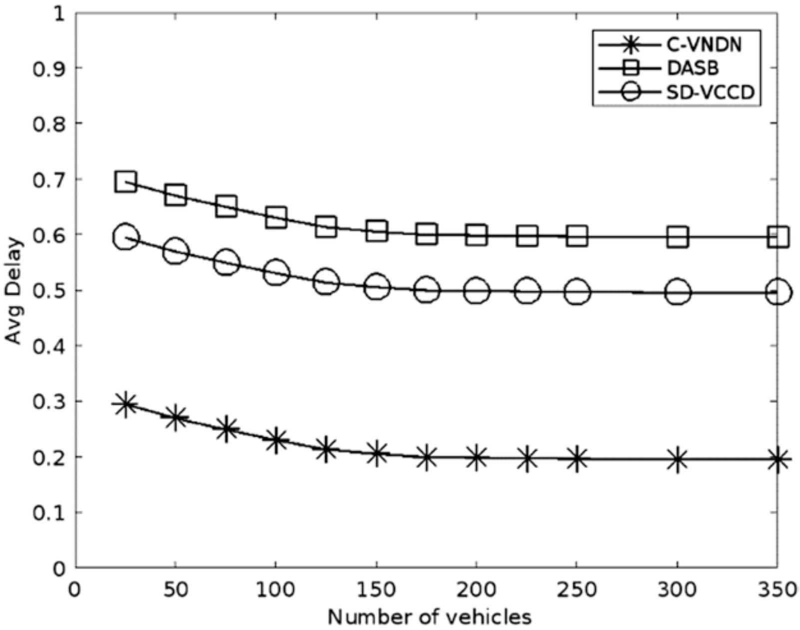

Fig. 15.9 Average delay(s) vs Number of vehicles

15.6 Conclusion

In this work, a virtual clustering-based content distribution scheme is presented that is based on a chain system built between vehicles for satisfying the consumer's request. The communication between nodes is achieved using Named Data Network that exploits its novel packet transmission characteristics for creating clusters as per the type of information. The whole model is controlled by a central SDN controller that manages the created chain network through a dynamic chain building procedure. The integration of SDN with Vehicular Named Data Network is especially useful for providing network support to intelligent applications in smart cities. The proposed scheme has been validated using ndnSim and obtained results indicate the satisfactory performance of SD-VCCD. Although still in its infancy, this scheme can be considered as a promising model that can be deployed with vehicular networks and provide effective network support for numerous vehicular applications in the future.

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