Hop-based congestion control mechanism for Vehicular Named Data Networking

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ABSTRACT

Vehicular Named Data Network (VNDN) is a content-centric approach to improve the efficiency of vehicular networks. A congestion control scheme in VNDN must consider the effects of multipath forwarding, network caching, and multicast delivery. Literature on VNDN architecture indicates Congestion control is one of the key issues while designing the protocol for communication. Traditional congestion control mechanism is basically designed for end-to-end connections and it does not fit into the Named Data Networking (NDN) architecture, where-in the contents can be retrieved from multiple sources through multiple paths. In the proposed work, a hop based congestion control mechanism is used, where-in each router is indulged with hop count number, if it exceeds hop count number, the interest packets are dropped accordingly and does not forward it to the other router and thus congestion is controlled.

Keywords— Congestion Control; Information-centric Network (ICN); Named Data Networks (NDN), Interest packet; Data packet

I. INTRODUCTION

Vehicular AD-Hoc Networks (VANETs) have gained much more popularity in the field of automotive manufactures to academic researchers for over a decade because they support varieties of transportation applications such as traffic flow controllers, safe driving and navigation assistance among others [1]. Vehicular Ad-Hoc is sub category of MANETs, and their creation was basically to focus on communication among vehicles in day to day life. Nowadays applications which are basically designed for vehicles have a direct connection to main server only to fulfil their requirements and must be guaranteed in obtaining Quality of Experience (QoE), Quality of Service (QoS) to users. Applications of VANETs generally fall in two categories: safety and infotainment application where safety application include road accident caution, traffic related data, weather conditions, while infotainment applications are those which include advertisement, video streaming, navigations [2]. In traditional TCP/IP architecture the above-mentioned applications require a high end-to-end connection where in source will be holding certain information and for instance consider a server is located far away from the client/requester node, and since VANETs examine only vehicles, connections are not stable since vehicles do keep changing their location in an unpredictable way while moving with high speed.

In order to overcome from TCP/IP related issues, Named Data Networking (NDN) has been proposed as new internet architecture to communicate contents in the future internet. The allure of NDN is that it addresses the content rather than a device i.e. it enables nodes/vehicle to name the needed data instead of naming destinations IP address. In order to consider NDN as more information centric, each node of NDN implemented consists of three data structure named as Content Store (CS), Pending Interest Table (PIT) and Forwarding Information Base (FIB) [3]. CS is the cache memory, once the interest packets are gone through the routing path the content will be stored in it. The PIT, records the outgoing IP (Interest Packet) for particular content/name and FIB is the final stop before the data is sent out to the web and also its stores the prefixes and interfaces which is further used to forward the data.

NDN has been adapted in VANETs hence it is named as Vehicular Ad-hoc Named Data Networking (VNDN) [4]. Basic working of VNDN brings several challenges such as Consumer/producer mobility, interest and data packets flooding, Broadcasting storm and so on. Due to the broadcasting nature of the mobility medium, the same interest packets are received by multiple nodes, as a result broadcasting multiple copies of data back to the user causes congestion [5]. Therefore, in the proposed work, a hop based method is used to solve the given issue. In proposed hop based congestion method, each vehicle will broadcast an interest packet which includes hop counter

(h) value, if the transitional node is not an provider upon receiving any interest packet, then it automatically increments h value, simultaneously it also creates PIT entry with the current hop value, and then forwards the interest packet. If hop count limit exceeds, interest packets are dropped accordingly and does not forward it to other vehicle/nodes and thus congestion is controlled by reducing the unwanted duplicate packet transmission in the network.

II. RELATED WORK

In this section, literature related to VNDN and congestion control mechanism is presented. Grassi et al. [6] proposed a Vehicular named-data networking prototype which controls the broadcast storms in wireless scenarios. The authors proposed Navigo, which is location based forwarding procedure for vehicular named data networking. Navigo addresses certain challenges such as sudden change in the network, issues related to connectivity in a vehicular network. Navigo does not forward a packet to any specific vehicle or to a moving car, instead Navigo aims at fetching the data from multiple providers of that content. Coutinho et al. [7] have introduced content-based protocols to improve data distribution in vehicular networks. The aim of this paper is to control the flooding of interest packet traversal for content discovery in VNDN. Thus, a location -based content distribution protocol for IP packets traversal towards that particular area which had recently discovered content-based source vehicle is proposed. The protocol mainly puts leverages on recently discovered content- based vehicle to control the transmit IP to the area where the content source was actually located. It also proposes the decrease of duplication Interest traversal at each hop. The proposed protocol faces challenges such as discovering location information of that particular vehicle which has the desired content in content store (cache), and also the data requester should also switch into the interest flooding whenever the next hop is not in the neighborhood. Syed Hassan et al. [8] proposed CONET mechanism. The main idea of the CONET is to allow the user vehicles to start hop counter in the interest package and upon receiving that interest by any provider to include Time to live with data message. Therefore, TTL basically includes no of hops, traversal of data packets back to the consumer, hence the result shows that the CONET forwards a smaller number of data messages while achieving ISR, it also minimizes the overall Interest Satisfaction Delay. Carofigilio et.al [9] proposed Hop-by-Hop receiver driven interest control protocol which aims at regulating user request either at the intermediate node or at the receiver node by interest shaping. The results infer that receiver driven protocol is very stable and also provide equilibrium, it also regulates congestion and controls the overhead. The proposed works in literature try reduce congestion by considering location, data behavior and interest packet propagation. In this paper, a hop count based mechanism is used to control the congestion.

III. HOP BASED CONGESTION CONTROL MECHANISM

In naive VNDN, contents can be retrieved from multiple sources and through multiple paths. Whenever the interest packets are not found in FIB, it will broadcast the request. Hence, all other routers which are inter-connected receive the request. Upon accepting incoming interest request, each router will again check in their data structure, if the data packet is present. If the data packets are not present for the requested interest packet then the router will again forward the interest packets to other routers which leads to congestion as shown in Fig1. In order to control congestion, hop-by-hop mechanism is performed in each routers. In Naïve VNDN, Interest packets which is sent consist of various information field such as Names, Nonce value and interface information, whereas Hop based congestion method also enables every VNDN enabled vehicle to include one additional field such as hop field, in-order to keep track of hops traversed by Interest packets. Hence the value h determines the hop the interest packet has taken. Routers/vehicle are indulged with hop count number, if it exceeds hop count number, then interest packets are dropped down and they do not forward it to the other router and thus congestion is controlled.

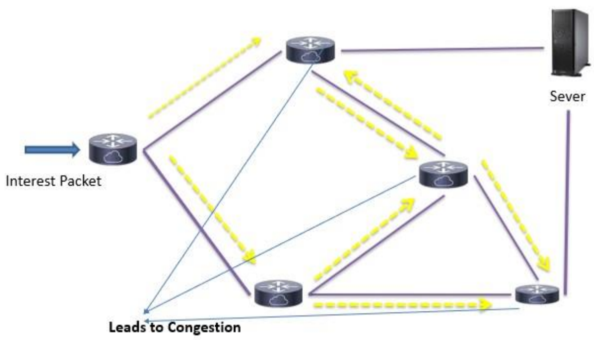

Fig 1: Broadcasting of VNDN leading to congestion

Proposed Algorithm 1

Interest Packet reception in proposed VNDN:

```
Received [Name, Selector(s), NONCE, h]
if Content Not in CS then
        if Name Not in PIT then
                h = h+1  #increment hop counter
                Add [Name, NONCE, h, Face] in
                PIT
                Replace h in Interest
                Forward Interest using FIB
        else
                Drop Interest
        end if
else
        DATA [Name, Meta-Info, TTL,
        Content]
        Send Data
end if
```

In naïve VNDN, interest packets which is sent has various fields such as Name, Selector, Nonce value, whereas the proposed method enables every VNDN architecture to include additional hop-count field *h*, in-order to determine of how much hops the interest packets have traversed and if the hop count value is exceeded, then the interest packets are dropped, and no more packets are forwarded further.

Proposed Algorithm 2

Data Packet reception in proposed VNDN:

```
Data [Name, MetaInfo, Content]
if Name in PIT then
        if Face is Application then
                Node Received DATA
        else
                if h in PIT ≤ HCL
                    HCL = HCL-1
                    Update HCL value in Data
                    Forward DATA to Face
                    Remove [Name, NONCE, h, Face] from PIT
                    end if
        end if
else
        Drop data
```

In the proposed hop method, if an intermediate provider receives the data packets, it compares hop count value (h) with the Hop Count Limit (HCL). If the h value is lesser than or equal to HCL, the value is updated in the data and the data is forwarded to appropriate Face else the data is considered to have travelled a larger distance than expected and is dropped to avoid further broadcasting of the packet.

IV. RESULTS AND DISCUSSION

In this section, a comparison of the naïve VNDN and the hop count method is presented. Ns-3 tool is used for simulation and NDN forwarding daemon is installed in every node. Traffic data is generated from SUMO tool, which consists of 5 Km, two-lane highway road. An average of 20 simulations are run for each scenario and the obtained results are tabulated and plotted. The simulation parameters are summarized in Table 1.

Table 1: Simulation Parameters

Network Simulator	Ns-3

Traffic Data	SUMO
Simulation Time	30 s
Network Size	50-120
Vehicle Speed	50-110 km/hr
RSUs	5
Wi-Fi Manager	AARFI Wi-Fi Manager
Frequency band	5.9 GHz
Transmission Power	6.3 mW

Three metrics are considered for comparing the performance of naïve VNDN and hop count method.

- Copies of data packets processed (CDPP): It shows, number of the copies of data packets are being processed in a given network
- Interest Satisfaction Rate (ISR): Total number of received data packets that were received by the requester divided by the total number of interest packets are being sent.
- Interest Satisfaction Delay (ISD): Delay occurred while traversing Interest packets in a given network.

To get a better insight of the performance, these quality metrics are being evaluated against the network size and vehicle speed.

Copies of Data Packets Processed (CDPP)

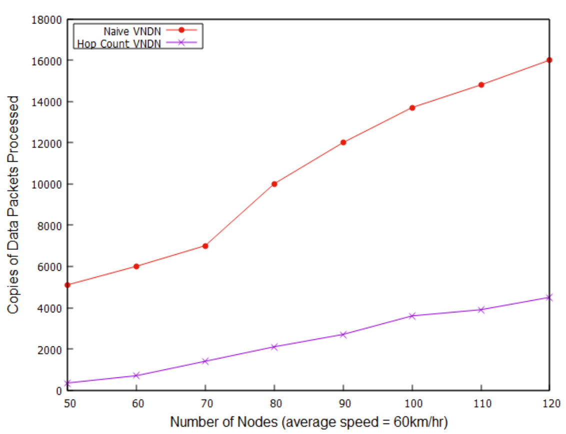

Fig 2: CDPP vs Varying Network Size

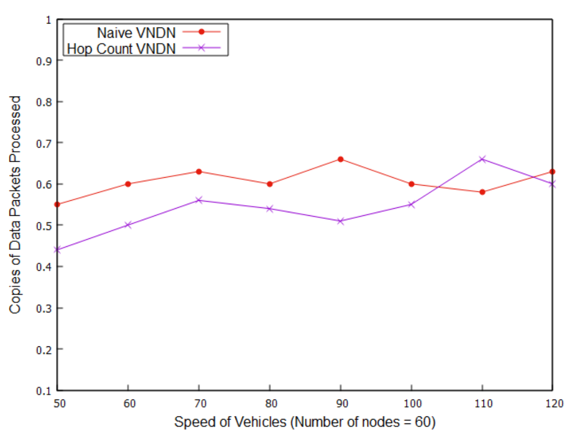

Fig 3: CDPP vs Varying Vehicle Speed

The number of data packets processed increases as the network size increases, this can be observed in Fig 2. The hop count method reduces the data packets processed since the packets do not travel beyond the HCL value. The speed of the network has no major impact to the CDPP value (Fig 3.)

Interest Satisfaction Ratio (ISR)

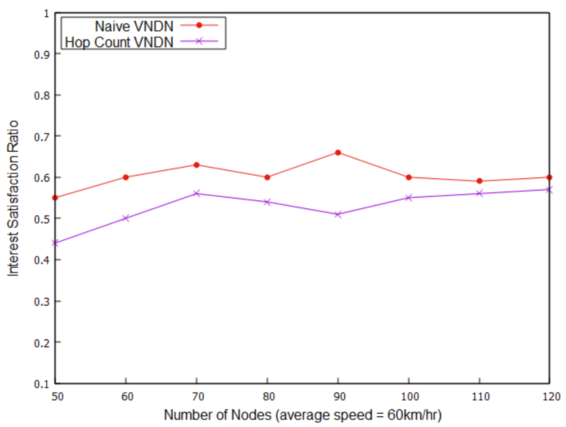

Fig 4: ISR vs Varying Network Size

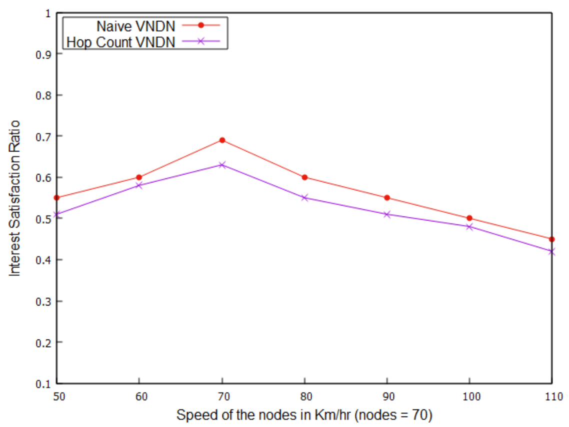

Fig 5: CDPP vs Varying Vehicle Speed

ISR has reduced by 4-6% in the hop count method, since the producer nodes in few scenarios can be present beyond the estimated hop count value. From Fig 4, it can be observed that varying network size does not impact ISR value, however, it decreases with increasing vehicle speed (Fig 5) since there is limited connectivity at high speeds and the packets cannot be transmitted completely.

Interest Satisfaction Delay (ISD)

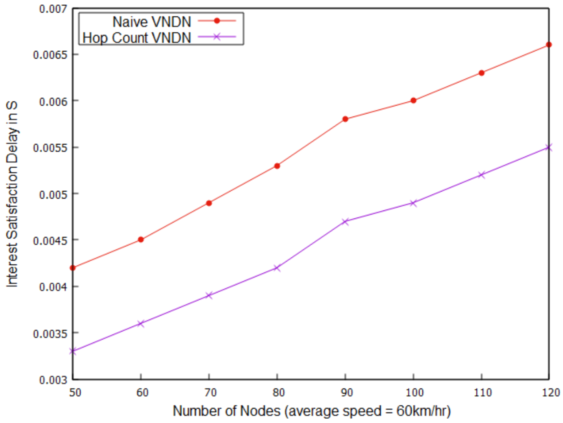

Fig 6: ISD vs Varying Network Size

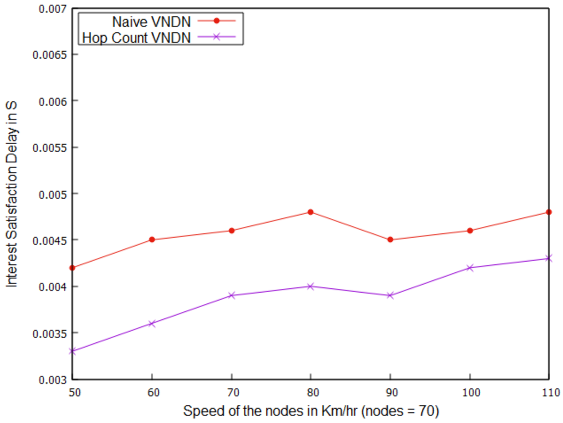

Fig 7: ISD vs Varying Vehicle Speed

The ISD value of hop count method is reduced by 12-15% as compared to the naïve VNDN. Increasing number of vehicles will add to the delay, this can be observed in Fig 6. The delay increases with speed (Fig 7) because of the retransmission due to intermittent connectivity.

V. CONCLUSION

The previous sections presented an introduction to VNDN and a hop count mechanism to reduce congestion in the vehicle networks. The proposed method was evaluated by considering three metrics namely, ISR, ISD and CDPP and compared against naive VNDN architecture. The simulation results under various scenarios show that the number of data packets processed reduces significantly in the hop method. Although the ISR reduces slightly in case of hop method, the delay is reduced. Naïve VNDN requires a congestion control mechanism and the proposed hop count method reduces the duplicate data packets in the network, and thereby reduces the congestion. Future work includes considering the mobility of the producer and further reduce the copies of data and interest packets.

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