Smart Forwarding in NDN VANET*

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ABSTRACT

Routing solutions for NDN VANET that use location information can be inadequate when such information is unavailable or when the vehicles' locations change very fast. In this paper, we propose CCLF, a novel forwarding strategy to address this challenge. In addition to leveraging vehicle location information, CCLF takes into account content-based connectivity information, i.e., Interest satisfaction ratio for each name prefix, in its forwarding decisions. By keeping track of content connectivity and giving higher priority to vehicles with better content connectivity to forward Interests, CCLF not only reduces Interest flooding when location information is unknown or inaccurate, but also increases data fetching rate.

CCS CONCEPTS

• **Networks** → *Routing protocols*; *Mobile ad hoc networks.*

KEYWORDS

NDN, VANET, Routing, Forwarding

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1 PROBLEM AND MOTIVATION

Named Data Networking (NDN) [8] is a new Internet architecture that breaks free from IP's host-centric architecture and embraces a data-centric communication model. In NDN, a consumer node does not have to know the address of the data producer. As long as the name of the data is known, an Interest packet carrying the data name can be sent to retrieve the data. This data-centric approach to communication suits vehicular networking where it is very inefficient and sometimes impossible to keep track of the whereabouts of data producers. Previous studies (e.g., [2–4]) have shown how VANET applications can benefit from NDN.

Many routing and forwarding schemes for VANET are topology-based, but such schemes tend to have high costs in a mobile environment due to frequent updates of the routing/forwarding table. Another popular approach is to forward packets based on the geographic location of the data producer (e.g., [3, 4]) However, these schemes need to resort to broadcast when the location information is unavailable. The authors in STRIVE [5] proposed a centrality based forwarding approach where a vehicular node's importance is taken into account in forwarding, but it requires message exchanges to know each neighbor's centrality and it does not differentiate the centrality of a node for different content.

In this paper, we propose a new forwarding strategy for NDN VANETs called *Content Connectivity and Location-Aware Forwarding (CCLF)*. CCLF forwards packets based on both data's location information and vehicles' content connectivity. It uses per-name prefix Interest satisfaction ratio to quantify content connectivity, i.e., the success of a vehicle in fetching data for a particular name prefix. Each vehicle that receives an Interest sets a waiting timer and forwards the Interest when the timer expires or discards the Interest when it hears another node forwarding the Interest. The timer is set such that those nodes with better content connectivity for the Interest and shorter distance to the data location will have a higher chance in forwarding the Interest.

As CCLF does not depend solely on location information, it can be much more robust than other VANET forwarding strategies in situations where vehicle location changes very fast. In addition, it can reduce Interest flooding when location information is unavailable. We are in the process of evaluating this strategy by comparing its message overhead and data fetching rate with other VANET forwarding strategies.

2 CCLF STRATEGY

CCLF strategy allows a vehicle to consider both content connectivity and location information while making forwarding decisions. We use a data structure called Connectivity-Location (C-L) Tree, which is an augmentation of the Name-Tree structure of NFD [7]. Each node of the tree holds a name

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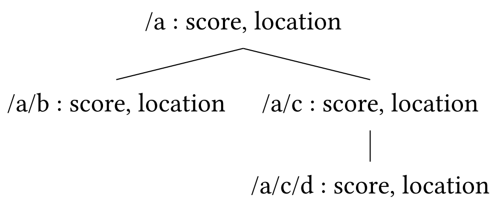

Figure 1: An example C-L Tree

prefix along with the corresponding connectivity score (CS) and location information (Figure 1). The CS of a name prefix is calculated using the total Interests and Data packets forwarded for this prefix and its children (see Equation (1)). CS quantifies the connectivity of a vehicle for the name prefix - the more data it can fetch for that name prefix, the higher the score, and our algorithm will give a higher priority for this vehicle to forward Interests under the name prefix.

$$CS_{prefix_j} = \frac{D_{prefix_j} + \sum_{i \in Children_T(j)} D_{prefix_i}}{I_{prefix_j} + \sum_{i \in Children_T(j)} I_{prefix_i}}, \quad (1)$$

where D_{prefix_j} is the Data count for prefix j, I_{prefix_j} is the Interest count for prefix j, and $Children_T(j)$ denotes the Children of prefix j. When serving data, producer attaches the corresponding name prefix to the data packet. Upon receiving the packet, a node in the C-L tree is created if the name prefix is not already there, and the corresponding CS is updated. We use the weighted average instead of the instantaneous value of the CS (Equation (2)) in forwarding.

$$\begin{aligned} \widehat{CS}_{N+1} &= \alpha \cdot \widehat{CS}_N + \beta \cdot CS_{N+1} \\ \alpha + \beta &= 1 \end{aligned} \quad (2)$$

When NFD receives an Interest, the forwarding strategy finds the longest matched prefix in the C-L tree for this Interest, and retrieves the corresponding CS and location information. The location information is used to calculate the location score (LS) (Equation (3)).

$$LS_{prefix_j} = 1 - \frac{Dist_{me}}{max(Dist_{me}, Dist_{prev})}, \quad (3)$$

where $Dist_{me}$ is the distance from this vehicle to the destination, $Dist_{prev}$ is the distance from the previous vehicle to the destination. The CS and LS of the prefix are then used to calculate the *weight* of the vehicle, i.e., its priority in forwarding the Interest (Equation (3)). Vehicles closer to the data producer (higher LS) and more successful in fetching data under the name prefix (higher CS) are given priority in forwarding the Interest.

$$weight_{prefix_j} = \alpha \cdot LS_{prefix_j} + \beta \cdot \widehat{CS}_{prefix_j} \quad (4)$$

The vehicle will suspend the forwarding of the Interest till a Waiting Timer expires (Equation (5)). If it receives the same Interest during this time period, it cancels the forwarding of the interest.

$$timer = \begin{cases} \frac{1}{weight}, & \text{if } weight > 0 \\ 0, & \text{otherwise} \end{cases} \quad (5)$$

If the vehicle does not have any information (i.e., $CS = 0$ and $LS = 0$), the $timer$ will be zero and the vehicle will broadcast the Interest immediately.

When a vehicle receives a data packet, it updates the Interest and Data count for the corresponding name prefix and its ancestor prefixes. It also recalculates the CS values periodically based on Equation 1 and 2.

3 IMPLEMENTATION AND EVALUATION

We have enhanced NDN's link adaptation protocol, NDNLP [6], to support a Location header. The header consists of two optional fields: Destination Location and Previous Hop Location. We also use an existing NDNLP header, Prefix Announcement, to allow producers to include a name prefix in their data packets. We implemented the strategy as a new strategy module in NFD.

We have been using ndnSIM [1] to test the CCLF strategy in simple topologies. We plan to do extensive evaluation with larger and mobile topologies, and compare our scheme with VNDN [3], NAVIGO [4], and STRIVE [5].

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