Preference-aware Fast Interest Forwarding for Video Streaming in Information-Centric VANETs

Mu Wang*, Changqiao Xu*, Shijie Jia†, Jianfeng Guan*, Luigi Alfredo Grieco‡
*State Key Laboratory of Networking and Switching Technology,
Beijing University of Posts and Telecommunications, Bejing 100876, China
*Academy of Information Technology,
Luoyang Normal UniversityLuoyang 471022, China
‡Politecnico di Bari, Bari, Italy
{wangmu, cqxu, jfguan}@bupt.edu.cn, shjjia@gmail.com, alfredo.grieco@poliba.it

***Abstract*—Information-Centric Networking (ICN) focuses on data dissemination instead of host communication, and it is a promising solution for video streaming in Vehicular Ad-hoc Networks (VANETs). In Information-Based VANETs, content copies can be cached by arbitrary mobile nodes in the networks. Thus, it is required to optimize the routing of content requests (referred to as *Interest* packets) in order to quickly locate potential content providers as soon as possible. This article proposes a Preference-aware Fast Interest Forwarding for video streaming in ICN-based VANETs (PaFF). In PaFF, each mobile user creates a Highly Preferred Content Table (HPCT) to maintain the content caching status of nodes who have similar mobility patterns and video playback behavior. Based on HPCT, a preference-aware forwarder selection mechanism is proposed to select the next hop of *Interest* packets in order to minimize latencies and maximize reliability. Simulation results show that PaFF achieves a considerable improvement in terms of start-up delay and cache hit ratio while incurring almost the same overhead with respect to state-of-art solutions.**

***Keywords*—video streaming, information-centric networking (ICN), VANETs, Interest packet forwarding.**

I. INTRODUCTION

Vehicular Ad-hoc Networks (VANETs) enable direct communications among vehicles [1][2] and video streaming sharing is a key service in this field [3]-[5]. Unfortunately, the IP protocol cannot support effectively the high degree of mobility entailed by a VANET because the network topology is subject to frequent modifications, which significantly impact the efficiency of video streaming. Information-Centric Networks (ICNs) [6] emerged as a novel paradigm to reshape the future Internet, by providing network primitives grounded on contents rather than addresses. Based on its design idea, ICNs employ in-networking caching and routing by name to achieve ubiquitous content access for end users and native support to mobility, and thereby gaining momentum in VANETs [7]-[9]. Generally speaking, in ICN architectures: 1) a data consumer issues a request for a named content; 2) the network routes the request and locates a set of candidate data providers; 3) the asked data item is sent back to the consumer but in the reverse direction. Without lack of generality, the data request will be referred to as *Interest* packet as in the terminology of the CCN architecture[1].

The name based routing design of ICN decouples content from the hosts, as a result, the requests of users can be responded by a nearby provider instead of routing to the source. Therefore, ICNs provide more efficient content sharing with respect to traditional IP networks, which has been treated as a promising solution for content-based applications in VANETs, such as video streaming [9][10]. Because users are playing role of content consumers as well as content carriers in ICN-based VANETs, namely content can be cached by arbitrary nodes in ICNs, hence how to route *Interest* packets to potential data providers as fast as possible to ensure the required timeliness to users is an critical issue. Current ICNs architecture such as Named Data Networking (NDN)[11] broadcasts the *Interest* packets via the network interface in wireless environment which may results in *Interest* flooding. Specifically, *Interest* packets will be sent to all one-hop neighbors during the forwarding process in order to fast discover the content providers. As a consequence, multiple content providers may be discovered. All these providers will return the data packets and redundant data will be discarded by consumers, which waste huge bandwidth. To avoid Interest flooding, solutions in [12][13] select the farthest neighbor node at each hop as the forwarder to broadcast Interest packet. However, the forwarder selection procedure requires each forwarder to broadcast the Interest packet after a given delay, which may brings negative effect on content lookup speed and hence is not suitable for delay sensitive video streaming.

Several studies focus on unicast-based Interest forwarding solutions to achieve fast content lookup while maintaining low bandwidth consumption. Ahmed $et\ al.$ propose a scheme named Robust Forwarder Selection (RUFS) in [14], which enables mobile nodes exchanging recent content lookup success information and forwarding *Interest* packets to node that has already successfully routed the same request. Lu $et\ al.$ [15]

---

[1] The key contribution of this paper applies to any ICN architecture based on hierarchical names, in network caching and data retrieval in pull mode. Without loss of generality, we framed our proposal in the context of CCN to simplify the presentation. Named Data Networking can be supported too without any significant modifications.

propose a social-tie based Interest forwarding scheme(STCR) which defines the centrality of mobile nodes according to the number of encountered nodes. Each node forwards the Interest packet to next-hop which has higher centrality value, since nodes with higher centrality encounter more mobile nodes and hence provide a higher lookup success rate. However, the routing information is collected via opportunistic interaction in above methods, which is easy to become invalid due to the cache eviction. As a consequence, the usage of maintained information is low. Besides, high speed movement of vehicles may result in quickly change of the routing path, these solutions require to frequently exchange routing information to guarantee the content lookup success rate.

Inspired by our previous study which reveals that users with similar video preference will have high probability of requesting the same video content [16]. Namely, nodes have high probability to find preferred video content in nodes with similar video preference. Thus, maintaining cache status of nodes with similar video preference enables users fast locate video content which has high probability to be viewed. Due to the high dynamic of vehicular nodes in terms of mobility which results in the intermittent of connectivity, it is also necessary to consider the mobility pattern when forwarding the *Interest* packet and deliver data among nodes with similar movement behavior to reducing the jitter of delivering performance. Therefore, we hereby propose a **Preference-aware Fast Interest Forwarding for Video Streaming in ICN-based VANETs** (**PaFF**) which consider the similarity of video preference and mobility when forwarding the Interest packet. In PaFF, each node selects a set of nodes with similar mobility and video preference as associate nodes. A *High Preferred Content Table* (HPCT) is created at each node to maintain the cache status of associate nodes. Based on the HPCT, we further propose a preference-aware forwarder selection mechanism. For requested video content that matches an entry in HPCT, the receiving nodes directly forward the *Interest* packet to the next-hop who has nearest distance to the content provider. If the requested content cannot match any entry in HPCT, nodes will select next-hop of forwarder by considering the preference degree on requested content and similarity of mobility pattern. In addition, extensive simulation campaigns have been carried out, showing that comparing with state-of-art solutions, PaFF achieves better results in terms of delay in finding data and cache hit ratio while incurring almost same maintain overhead.

II. CONSTRUCTION AND MAINTENANCE OF HPCT

In this section, we first describe how to select associate nodes on the basis of mobility similarity and video preference similarity. Then, we discuss the construction procedure of the HPCT in each nodes. Finally, we illustrate the maintenance of HPCT.

A. Associate Nodes Selection Mechanism

The selection of associate nodes relies on three basic mechanisms: 1) estimation of similarity of mobility patterns in the neighborhood; 2) estimation of preference agreements in the neighborhood; 3) discovery of associated nodes beyond the one hop neighborhood.

In order to explain the procedure of selecting associate nodes, we first describe how to estimate the mobility similarity between one-hop neighbors. We assume that each vehicle is equipped with GPS to record the movement speed and periodically announce the movement speed to one-hop neighbours.

Considering that the VANETs scenario is a two-dimension plane, the velocity of each mobile node x can be represented as two-dimension vector $\mathbf{s}_x = (x_1, x_2)$. Then, we can calculate the mobility stability between node x and y by following equation:

$$R\left(\mathbf{s}_x, \mathbf{s}_y\right) = \frac{x_1 y_1 + x_2 y_2}{\sqrt{x_1^2 + x_2^2} . \sqrt{y_1^2 + y_2^2}} \tag{1}$$

$R\left(\mathbf{s}_x, \mathbf{s}_y\right)$ is the cosine similarity between $\mathbf{s}_x$ and $\mathbf{s}_y$, large value of $R\left(\mathbf{s}_x, \mathbf{s}_y\right)$ indicates high consistency of movement trajectory of x and y. Namely, neighbour node y with high $R\left(\mathbf{s}_x, \mathbf{s}_y\right)$ will stay in one-hop range of x for a relatively long time. Therefore, considering similar movement behavior among can reduce the occurrence of routing failure caused by routing path dynamic as much as possible. Based on the equation, we select neighbour nodes whose value of $R\left(\mathbf{s}_x, \mathbf{s}_y\right) > \theta_1$ as the candidate associate nodes, where θ_1 can be considered as a tunable threshold.

Each node further selects one-hop associate nodes from candidate associates node set according to the video preference similarity. To estimate the video preference similarity, each node forms a following data structure for recording user playback behavior history:

$< videoname, type, playbacktime >$

$videoname$ is the hierarchical name of watched video. $type$ denotes the type of video, such as actions and comedy, this type information of video can be easily obtained from current video website such as Youtube, Youku, PPLive, etc. Besides, it is worth to mention that a video can be categorized into one or multiple types. For instance, movie MAD MAX 4 in Youku is categorized into actions, science fiction and adventure. $playbacktime$ records the length of time interval that user spend on corresponding video. To estimate the playback similarity between two nodes on the basis of playback behavior history, we define a non-negative parameter $p_i^x \ (1 \leq i \leq k)$ as the **preference degree** of user x on type video i. The calculation rule of p_i^x is given as following equation:

$$p_i^x = \sum_{v_j \in V_x} I_i\left(v_j\right) \frac{p_x\left(v_j\right)}{p_{total}\left(v_j\right)} \tag{2}$$

where V_x denotes the set of videos watched by x, $p_x(v_j)$ and $p_{total}(v_j)$ are the $playbacktime$ of corresponding video in playback behavior history and total video length of v_j, respectively. $I_i\left(v_j\right)$ is a indicator function as equation (3):

$$I_i\left(v_j\right) = \begin{cases} 1, \text{ if } v_j \in T_i \\ 0, \text{ otherwise} \end{cases} \tag{3}$$

T_i denotes the set of video in type i. High p_i^x value indicates x spend more time on video type i, as well as have more

Algorithm 1: One-hop associate Nodes Discovery

```
input: one-hop neighbour node set $N_x$ of node $x$;
output: candidate associate node set $C_x$ and associate node set $A_x$ of $x$;
for $y \in N_x$
  calculate $R(\mathbf{s}_x, \mathbf{s}_y)$ according to equation (1);
  if $R(\mathbf{s}_x, \mathbf{s}_y) \geq \theta_1$
    add $y$ into $C_x$;
  end if
end for
for $y \in C_x$
calculate preference similarity value according to the $d_2(P_x, P_y)$ in equation (5);
end for
sort the nodes in $C_x$ in ascending order according their preference similarity value;
for ($j = 1$, $j <= h$,$j++$)
   $A_x[j] = C_x[j]$;
end for
return $A_x[j]$ and $C_x[j]$;
```

potential interested on video in type i. Based on p_i^x, a k-dimensional vector $\mathbf{P}_x$ is formed for each mobile user x as equation (4):

$$\mathbf{P}_x \triangleq (n_1^x, n_2^x, n_3^x, \ldots, n_k^x)^T \tag{4}$$

$\mathbf{P}_x$ can be treated as the playback behavior pattern of x, where n_i^x is the normalization value of corresponding p_i^x which is calculated according to following equation:

$$n_i^x = \frac{p_i^x}{\sum\limits_{j=1}^{k} p_i^x} \tag{5}$$

Because $\mathbf{P}_x$ is n-dimensional vector with small scale and hence can be totally appended into MAC layer beacon message for exchanging with one-hop neighbours. In order to measure the similarity between two users, we treat $\mathbf{P}_x$ as a point in k-dimensional Euclidian space $\mathbb{R}^k$ space. Therefore, similarity between any two users x and y can be measured by the Euclidean distance between corresponding points in $\mathbb{R}^k$ as equation (6):

$$\begin{aligned} & d_2(\mathbf{P}_x, \mathbf{P}_y) = \|\mathbf{P}_x - \mathbf{P}_y\|_2 \\ & = \left(\sum_{i=1}^{k} [n_i^x - n_i^y]^2 \right)^{\frac{1}{2}} \end{aligned} \tag{6}$$

According to (6), the smaller of distance $d_2(\mathbf{P}_x, \mathbf{P}_y)$ is, the higher playback behavior similarity between x and y. Mobile node x sorts one-hop neighbors in an ascending order according to $d_2(\mathbf{P}_x, \mathbf{P}_y)$ and choose the top h-th nodes as the one-hop associate nodes. **Algorithm 1** shows the pseudo code of above one-hop associate nodes discovery process. Based on one-hop associate nodes discovery, a Gossip-like method is employed in order to discover the remote associate node which is not in one-hop range. In this method, each node use a table named associate node table (ANT) to record name of associate nodes. Each node periodically exchanges ANT with one-hop associate nodes via MAC layer beacon message and update the their own ANT according to the receiving ANT. For instance, at very beginning, the ANT of node x only records name of one-hop associate nodes. After exchanging ANT with one-hop associate node y, the ANT will records the name of one-hop associates nodes of y. After several iterations, the ANT of x will consists all associate nodes in network which have similar mobility and video preference.

Content Name	**Content Provider Information**			
	node name	***hop counts***	***next hop***	***timestamp***
/domain/videos /video1.mpg	x_1	0	*null*	$time\_N_1$
	x_2	3	x_3	$time\_N_2$
	⋮	⋮	⋮	⋮
/domain/videos /video2.mpg	x_5	1	x_5	$time\_N_5$
	x_8	4	x_3	$time\_N_8$
	⋮	⋮	⋮	⋮
⋮	···			
/domain/videos /video*N*.mpg	x_3	1	x_3	$time\_N_3$
	x_9	4	x_6	$time\_N_9$
	⋮	⋮	⋮	⋮

Fig. 1: Illustration of HPCT in mobile node x_1

B. *HPCT Construction*

HPCT maintains the mapping between content name cached by associate nodes and corresponding information about associate nodes, which aims to support unicast-based routing. As shows in Fig. 1, each entry has five attributes in HPCT: $Content\ Name$, $node\ name$, $hop\ counts$, $next\ hop$, $timestamp$, where $Content\ Name$ indicates the hieratical name of corresponding video content, $node\ name$ denotes the content provider of corresponding content, $hop\ count$ denotes the distance from HPCT owners to content carrier, $next\ hop$ record which associate node should be select as next-hop forwarder and $timestamp$ records the update time of corresponding entry.

Considering the self-organizing of the VANETs, we propose a fully distributed method to construct the HPCT. A special *Interest* packet called HPCT *Interest* packet is designed. This packet contains the body content of HPCT and a content name which is defined as follows: "**/HPCT/user_name/time_stamp/**". "**/HPCT**" is a common prefix of all HPCT *Interest* packet, "**/user_name**" indicates which node does this HPCT belong to, "**/time_stamp**" denotes the generation time of this HPCT. The HPCT *Interest* packet is exchanged periodically among one-hop associates nodes and each node update the local HPCT according to the receiving HPCT *Interest* packets. For instance, assuming node x receives a HPCT *Interest* packet from y, if HPCT *Interest* packet of y contains the information about content name or content provider name that is not in HPCT of x, a new entry that record the corresponding information about content and content carrier will be created in HPCT of x. The $nexthop$ of this entry will be set to y and $hopcounts$ is equal to the value of hop counts between y and content carrier plus one. The *timestamp* will be set to the receiving time of this HPCT *Interest* packet. Otherwise, if HPCT *Interest* packet does not contains any new content name or content carrier with the respect to HPCT of x, x only update value of *hopcounts nexthop* and *timestamp* in each entries of local HPCT according to the HPCT *Interest* packet of y, the updated HPCT will be sent to one-hop associate nodes of x in next period. After several rounds of updating, cache status of all associate nodes will be recorded in local HPCT and thus the HPCT is constructed. The main advantages of this method is the dissemination range of HPCT *Interest* packet is limited in one-hop range which result in a low communication cost. Additionally, this method enable nodes be aware of the cache status of far end associate nodes without any centralized coordination or remote information exchange.

C. *HPCT Maintenance*

How to maintain the validation of entries in HPCT is another important issue since success rate of *Interest* forwarding highly relies on the validation of HPCT. We consider two cases that will cause the invalidation of entries in HPCT: 1) cache replacement occurs in associate nodes; 2) next hop associate nodes moves out the one-hop range. In first case, unlike other mobile device, vehicles have stronger storage capacity which enables to cache multiple video contents [13], hence video content can be resident in content store permanently and this case does not have significantly effect on HPCT validation. Thus, periodically HPCT exchanging proposed in previous section is enough for handle the cache replacement. For the second case, departure of associate nodes will cause change of routing path, which may result in lookup failure. To avoid routing failure when a one-hop associate node moves out communication range, node first delete the entries of whose *nexthop* is the departure node and send the updated node to all one-hop associate node immediately. The receiving node update the HPCT and exchange the updated HPCT with other associate nodes in next period. Besides, when routing failure occurs, the node in the end of routing path will sent back a ACK to announce the routing failure, on-path node will delete the entry of content carrier that caused routing failure in the HPCT after receiving the ACK.

III. PREFERENCE-AWARE FORWARDER SELECTION SCHEME

In this section, we mainly focus on the Interest forwarding process in PaFF. As we discussed, HPCT maintains the mapping between content name and information about content carrier, hence to support unicast-based Interest forwarding. However, if requested content is not in HPCT, a single next-hop should be selected as the forwarder. In this case, we select a node from candidate associate nodes set (excluding one-hop associate nodes) with similar mobility pattern and has highly interested in requested content as the next hop forwarder. We calculate the preference degree of each candidate associate node y on requesting video content v_h by following equation:

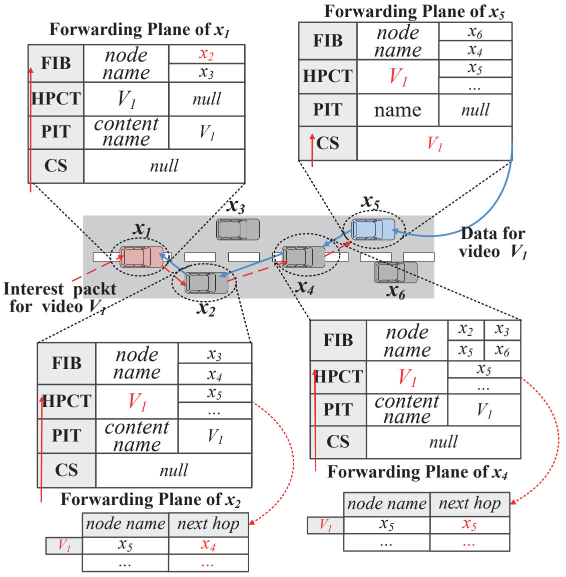

Fig. 2: Illustration of forwarding process in PaFF over VAENTs environment

$$p_y^h = \sum_{j=1}^{k} I_j\left(v_h\right) n_j^y \tag{7}$$

where n_j^y and $I_j\left(v_h\right)$ are the component of $\mathbf{P}_y$ and indicator functions as (3), respectively. We further normalized p_y^h according to (8):

$$H_{p_y^h} = \frac{\max_z p_z^h - p_y^h}{\max_z p_z^h - \min_z p_z^h}, \quad \text{for } z \in \mathcal{N}_x \tag{8}$$

where $\max_z p_z^h$ and $\min_z p_z^h$ denote maximum and minimum value of p_z^h among neighbors nodes of user x, respectively.

Based on equations (8) and (1), we select the candidate node with highest forwarding capability according to (9) as the next hop forwarder.

$$\arg\max_{y \in N_x} \left(1-\alpha\right) H_{p_y^h} + \alpha R\left(\mathbf{s}_x, \mathbf{s}_y\right), 0 \leq \alpha \leq 1 \tag{9}$$

Based on above discussion, when new *Interest* packet arrives in mobile node x, the Interest forwarding process will consist of four steps:

Step 1: mobile node first checks the local Content Store (CS) whether the requested content is in CS. If found, the data of requested video will directly sent back to upstreaming node via the incoming interface of *Interest* packet. Otherwise, turn to **Step 2**.

Step 2: mobile node checks whether to record the name of requested content into the own Pending Interest Table (PIT). If the PIT already contains an entry of requested content, forwarder only adds the incoming interface into the own PIT, then discards the *interest* packet and waits for data returning. Otherwise, if PIT does not contain the entry of requested content, a new entry for requested content which contains the content name and incoming interface will be created and turn to **Step3**.

Step 3: mobile node checks whether the name of requested content is in HPCT. If found, node directly forwards the *Interest* packet to next hop according to HPCT. If multiple content providers of requested content exist, node will choose the content provider with minimum distance to request content and forward *Interest* packet to corresponding next hop. Otherwise, if name of requested content is not in HPCT, turn to **Step 4**.

Step 4: node forwards the this *Interest* packet to next-hop according to Forwarding Information Base (FIB) if FIB contains the mapping between name of requested content and name of next hop. Otherwise, calculate the forwarding ability according to equation (9), and forwards the *Interest* packet to the candidate associate node with highest forwarding ability. Adding a entry that contains the mapping between name of next hop forwarder and name of requested video into FIB.

Fig. 2 shows a instance of forwarding *Interest* packet in PaFF. Forwarding plane of mobile vehicle x_1 receives a *Interest* packet for video content V_1, it first checks local content store (CS) and records the missing cache event in Pending Interest Table (PIT), and then searches HPCT without any match and forwards the *Interest* packet of V_1 to next-hop x_2 according to FIB. Node x_2 discovers in its HPCT that V_1 can be retrieved from content provider x_5 and then forwards this *Interest* packet to next-hop x_4; x_4 directly forwards request to content provider x_5 thanks to information in its HPCT, and x_5 returns the data packet along the reverse path.

IV. PERFORMANCE EVALUATION

In order to evaluate PaFF, we employ Network Simulator 3 (NS-3) to implement our proposed scheme. The simulation time is set to 1000s, mobile nodes and RSUs are equipped IEEE 802.11p WAVE network interface to support wireless communications for data transmission. The transmission range is 250m and data transmission rate is set to 10Mbps, which aims to support video streaming transmission. Mobile nodes advertise MAC layer beacon message every 100ms and exchange HPCT with social partners every 10s. To get more realistic result, we use SUMO 0.27 [17] to generate 1500x1000 m^2 real urban area which captured from Beijing digital map. The snapshot of area is shown as Fig. 4. The movement behavior of mobile nodes follows real trace of taxis in Beijing which captured from T-Drive trajectory data samples in[18] and movement speed varies from 15m/s to 20m/s according to the real urban environment. 33 RSUs are evenly deployed in the mobile environment to provide the initial content of video streaming for mobile users. All videos are divided into 20 chunks and streaming rate is 192kbps, each chunk is 30s long and about 720KB in size. The mobile users join the video streaming system following a Poisson distribution with $\lambda = 10$, which denotes the average number of nodes that join the system per second is 10. We also set 10 video types, and the number of videos in each type is set to 5.

We create 200 synthetic user viewing log entries based on the interactive actions, measurements, and statistics from [19]. Each user generates *Interest* packet for requesting video chunk and playback video content according to the created viewing log. According to the repeated test result, the threshold θ_1 and weight value α are set to 0.7 and 0.5, respectively. And h is set to the half of number of associate nodes. The performance of PaFF is compared with recently proposed RUFS [14] and SCTR [15].

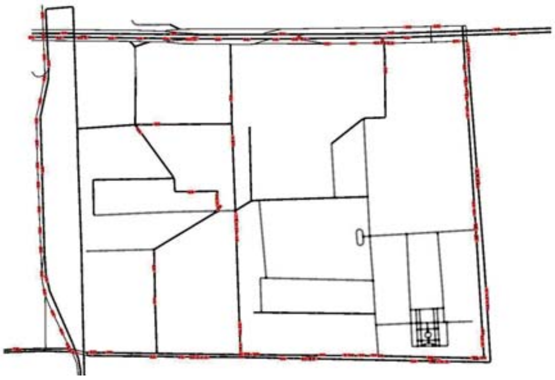

Fig. 3: Snapshot of urban area used in simulation test

We use following parameters to measure the performance:

Delay in finding data (**DFD**): the time interval between the transmission of an *Interest* packet and the reception of corresponding data items.

Cache Hit rate (**CHR**): the ratio of the number of cache hits to the sum of the number of cache hits and cache misses.

Maintain overhead (**MO**): the average data traffic generated per second(kb/s) for exchanging routing information (i.e. recent route success information in RUFS, content information and node social centrality collection in SCTR, HPCT, mobility and preference degree collection in PaFF).

Fig. 4 shows the DFD of three solutions with the variation of simulation time, the number of mobile nodes is set to 200. During the simulation time, the curves corresponding to the three solutions has shown the similar shapes, which a fast decline from 100s until 300s and then a stable trend with slightly fluctuation to the end. We observe that the green curve corresponding to PaFF achieves the lowest DFD when system is stable (after 300s). STCR is higher than PaFF but lower than RUFS. After 500s, three solutions PaFF, STCR and RUFS remains in stable and the value of which in are around 0.8, 1 and 1.3 respectively.

Fig. 5 illustrates that the DFD varies with the number of mobile nodes increasing. The trend of all solutions decline at first, but rising afterwards. This is because the number of content copies increase with scale of the network, which increases the chances to locate a closer content provider. This effect is counter balanced by an increased load due to a higher number of nodes so that, as soon as, the number of nodes grows over 120 all considered schemes incur a higher delay. In any case, PaFF outperforms RUFS and SCTR when the numbe of nodes is larger than 100.

In PaFF, the provider information of user highly interested content has already been maintained in the local PPCT, which enables avoid hop-by-hop content search. Thus, the SaFF achieves a low DFD in VANETs. STCR considers the social

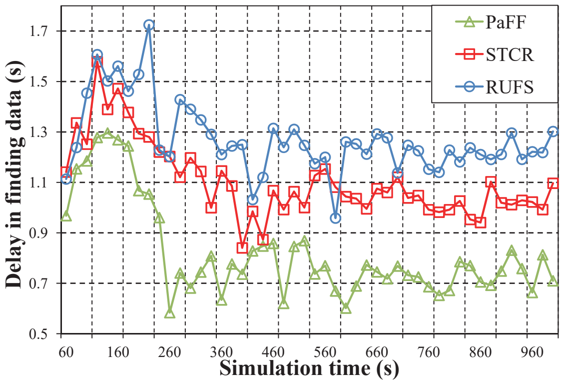

Fig. 4: Delay in finding data versus simulation time

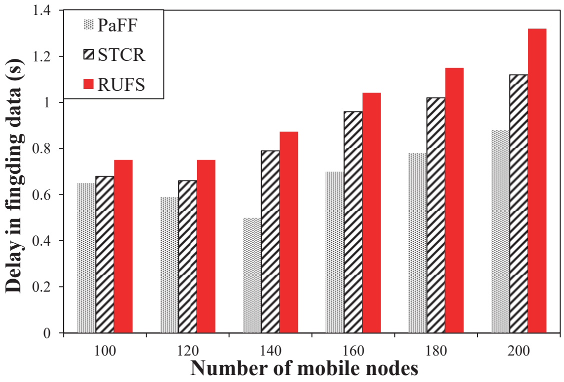

Fig. 5: Delay in finding data versus number of mobile nodes

centrality when forwarding *Interest* packet, which improve the robustness of Interest routing, however, social centrality cannot reveals the demand of user, namely, forwarding *Interest* packet to high centrality nodes may not improve the success of content lookup. RUFS formed a neighbor satisfied list for maintaining recent successful routing information to help select forwarder. However, the scale of content in ICN is large and behavior of user in terms of playback and mobility varies frequently, all these factors lower the reliability of this list. Thus, the DFD of RUFS is relatively high.

Fig. 6 shows the CHR of PaFF, STCR and RUFS during the simulation time. In this test, three solutions all employ cache everything everywhere (CEE) strategy as the cache policy. In CEE, mobile nodes cache every receiving data item and use LRU cache replacement mechanism to switch out the least recently used content copies when Content Store is full. From the figure we can see that the curve corresponding to the PaFF remains at a higher level than STCR and RUFS, especially when simulation time reaches 300. STCR has little improvement in terms of CHR when compare with RUFS.

The HPCT in PaFF enables user fast locating the potential desire video content, thus the *Interest* packet can be directly send to corresponding content provider, which results in a high CHR. Nodes in STCR always forward *Interest* packet to higher social centrality neighbors which has more information of demand content, yet high social centrality may not maintain the information of demand content, which may lengthen the searching path, namely miss hits in intermediate nodes and results in low CHR. The mobile nodes in RUFS list the recently search satisfied information of neighbor nodes, which can improve search efficiency. However, the dynamic of user behavior and network limit the accuracy of list and hence reduce CHR.

Fig. 7 shows maintain overhead of three solutions with the variation of mobile nodes numbers. The curve of PaFF raises slightly with the growing of mobile nodes, and curves corresponding to the STCR also reveals the similar trends but the maintain cost of which is higher than PaFF. RUFS maintains a relatively fast increasing trend and achieves the highest maintain cost after 140s. Because of the velocity is a two-dimensional vector and playback pattern is a n-dimensional vector, the communication cost of exchanging these two vectors is very small and can be ignored. The main MO in PaFF is HPCT exchanging among one-hop associate nodes. The number of one-hop associate nodes is less than number of neighbour nodes and thus achieves a relatively low communication overhead. On the other hand, due to the associate nodes are relatively stable in terms of mobility and do not need frequent message exchanging in order to guarantee the validation of HPCT. Therefore, the MO of PaFF remains relatively low when number of mobile nodes increase. In STCR, higher social centrality nodes will maintain more information of cache status. With the growing of system scale, the centrality of nodes also increase and hence maintain cost grows fast. Additionally, higher centrality nodes requires to maintain more information and to be responsible for more content lookup task, which results in load imbalance system. In RUFS, mobile nodes exchange recently satisfied search information with all encounter nodes, which will become a huge burden when scale of network is large.

V. CONCLUSION

This paper proposes PaFF, a novel preference-aware Interest forwarding scheme for video streaming in ICN-based VANTEs. PaFF allows mobile nodes create HPCT to maintain the cache status of associate nodes which has similar mobility and video preference. Based on HPCT, a preference-aware forwarder selection mechanism is proposed, aiming to support fast unicast-based *Interest* packet forwarding. We run the simulation over NS-3 and show that PaFF can achieve an improved content search efficiency in terms of the delay in finding data and cache hit ratio when comparing with state-of-art solutions. We also show the maintain cost of PaFF can be remained at a relatively low level. Future work will be how to combine PaFF with cache strategy for further improvement on the performance of sharing video streaming in a content-centric mobile environment.

ACKNOWLEDGMENT

This work was partially supported by the National Natural Science Foundation of China (NSFC) under Grant No. 61522103, 61501216 and 61372112, and by the "Bonvoyage" and "Green Community Efficiency Systems" research

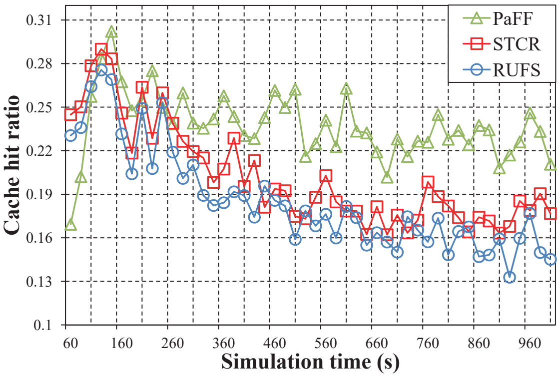

Fig. 6: Cache hit ratio versus simulation time

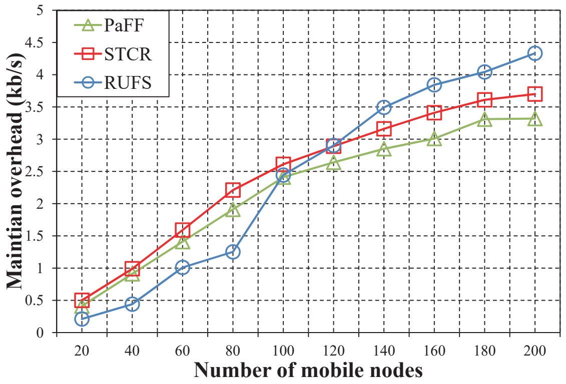

Fig. 7: Maintain overhead versus number of mobile nodes

projects funded by the EU H2020 program (grant agreement No 635867) and the Italian MISE (code B01/0768/03/X24), respectively.

REFERENCES

[1] J. He, L. Cai, P. Cheng and J. Pan,“Delay Minimization for Data Dissemination in Large-scale VANETs with Buses and Taxis,” *IEEE Transactions on Mobile Computing*, vol. pp, no. 99, 2015.

[2] M. Fadda, M. Murroni, V. Popescu, “Interference Issues for VANETs Communications in the TVWS in Urban Environments,” *IEEE Transactions on Vehicular Technology*, vol. 65, no. 7, pp.4952-4958, 2016.

[3] A.Mammeri, A.Boukerche, and Z. Fang,”Video Streaming Over Vehicular Ad Hoc Networks Using Erasure Coding,” *IEEE Systems Journal*, vol. 10, no. 2, pp. 785-796, 2016.

[4] C. Xu, S. Jia, M. Wang, L. Zhong, H. Zhang and G. M. Muntean, “Performance-Aware Mobile Community-Based VoD Streaming Over Vehicular Ad Hoc Networks,” *IEEE Transactions on Vehicular Technology*, vol.64, no.3, pp. 1201-1217, Mar. 2015.

[5] C. Rezende, A. Boukerche, H. S. Ramos and A. A. F. Loureiro, “A Reactive and Scalable Unicast Solution for Video Streaming over VANETs,”*IEEE Transactions on Computers*, vol. 64, no.3, pp. 614-626, Feb.2015.

[6] V. Jacobson, D. K. Smetters, J. D. Thornton, M. Plass, N. Briggs and R. Braynard, “Networking named content,” *Communications of ACM*, vol. 55, pp. 117-124, 2012.

[7] M. Amadeo, C. Campolo and A. Molinaro, “Content-Centric Networking: Is That a Solution for Upcoming Vehicular Networks?,” *ACM VANET*, pp.99-102, 2012.

[8] W. Quan, C. Xu, J. Guan, H. Zhang and L. A. Grieco, “Social cooperation for information-centric multimedia streaming in highway VANETs,” *IEEE 15th International Symposium on World of Wireless Mobile and Multimedia Networks (WoWMoM)*, pp.1-6, 2014.

[9] C. Xu, W. Quan, H. Zhang and L. A. Grieco,“GrIMS: Green Information-centric Multimedia Streaming Framework in Vehicular Ad Hoc Networks,”*IEEE Transactions on Circuits and Systems for Video Technology*, vol.pp, no. 99, 2016.

[10] C. Xu, P. Zhang, S. Jia, M. Wang and G.-M. Muntean,“Video Streaming in Content-Centric Mobile Networks: Challenges and Solutions,”*IEEE Wireless Communications*, vol. pp, no. 99, 2017.

[11] L Zhang, A. Afanasyev, J Burke, V Jacobson, K Claffy, P. Crowley, C. Papadopoulos, L. Wang and Beichuan Zhang, “Named data networking,” ACM SIGCOMM Computer Communication Review archive, vol.44, no.3, pp. 66-73, July, 2014.

[12] Y. T. Yu and M. Gerla, “Information-centric VANETs: A study of content routing design alternatives,” *IEEE International Conference on Computing, Networking and Communications (ICNC)*, 2016

[13] G. Grassi, D. Pesavento, G. Pau, R. Vuyyuru, R. Wakikawa and L. Zhang “VANET via Named Data Networking,” *IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*, pp. 410 - 415, July.2014.

[14] S. H. Ahmed, S. H. Bouk and D. Kim, “RUFS: RobUst Forwarder Selection in Vehicular Content-Centric Networks,” *IEEE Communications Letters*, vol. 19, no.9, pp.1616-1619, Sep.2015.

[15] Y. Lu, X. Li, Y. T. Yu and M. Gerla, “Information-centric delay-tolerant mobile ad-hoc networks” *IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*, pp. 428-433, 2014.

[16] C. Xu, S. Jia, L. Zhong and G. M. Muntean, “Socially aware mobile peer-to-peer communications for community multimedia streaming services,” *IEEE Communications Magazine*, vol. 53, no. 10, pp.150-156, Oct.2015

[17] http://www.sumo.dlr.de/userdoc/Downloads.html.

[18] https://www.microsoft.com/en-us/research/publication/t-drive-trajectory-data-sample/.

[19] Brampton et al., “Characterising user interactivity for sports videoon-demand,” *ACM NOSSDAV, Urbana-Champaign*, IL, USA, pp.1-6, Apr.2007.