A New ICN Routing Selecting Algorithm Based on Link Expiration Time of VANET Under the Highway Environment

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***Abstract*—Combining VANET with ICN (Information Centric Network), this paper proposes a new FIB (Forwarding Information Base) selecting algorithm-ECRMLET (Efficient Content Routing Model Based on Link Expiration Time). To build stable routings and reduce network traffic, our ECRMLET has the following designs: 1) we modify the structure of PIT (Pending Interest Table) by adding two domains: receive time and tolerance time; 2) we introduce the algorithm of LET (Link Expiration Time) to help with the content routing selection in FIB; 3) ECRMLET also gets the link availability probability to be auxiliary information for our algorithm.**

Keywords—ICN; VANET; LET; link available probability; FIB selecting algorithm

I. INTRODUCTION

As the most important part of Intelligent Transportation System (ITS) [1], the research of VANET (Vehicular Ad-hoc Network) has attracted more and more attention, but based on TCP/IP, the way using fixed IP address to manage nodes is inflexible and has a low efficiency. ICN (Information Centric Network) [2] focuses on whether the requests can be satisfied instead of hosts, it uses on-path [3] caching to reduce delay, and ICN features can make it easy to manage mobile nodes.

In this paper, we have applied ICN architecture to VANET. To reduce the useless traffic and improve the probability of Data packets' successful return, we design ECRMLET as follows: we modify the structure of PIT (Pending Interest Table); we introduce the algorithm of LET and Link availability probability to help with the routing selection in FIB; Finally we use the outgoing interfaces with a bigger LET and available probability to forward the Interest.

Then Section 2 describes the related works. Section 3 describes our main design. Section 4 analyzes the simulation results. In Section 5, we conclude our paper.

II. RELATED WORKS

A.VANET With ICN

In [4], authors conclude the main shortcomings for mobile network based on IP protocol and point out a new direction for the mobile network routing via named data, such as the DMND[5] model for VANET environment.

In [6], authors propose CCVN scheme, where the Interest forwarding is based on a counter, it divides Interest packets into *B-Int* and *A-Int*, and it also designs a timer for each Interest to deal with retransmission and data loss. But it lacks conflict detection and avoidance mechanism.

In [7], a scalable routing method using Bloom-Filter is presented, and its procedure utilizes hierarchical geographical partitioning. Simulation results show that it achieves comparable response time with CCN, but requires more overhead than the reactive CCN approach.

Grassi G and others put forward V-NDN [8]. Nodes in V-NDN would forward all received Data packets, Data cached before are always carried, forwarding process uses broadcast mode, and Data packets would be flooded to all the neighbors.

In [9], the researchers investigate the potential benefits of ICN in VANET and outline the fundamental design alternatives of two ICN-specific parameters: data source selection policy and caching policy, it also proposes a new shortest path geo-forwarding mechanism for urban VANET.

B. LET and Link Availability in Mobile Network

In [10], the author proposes a ranging-based link availability routing scheme. It modifies the definition of link availability and makes a tradeoff between link availability and network traffic. Moreover, based on the urban scenario, [11] divides four different motion cases, then it deduces the calculating formulas for link availability probability.

By using the Dynamic Source Routing (DSR) [12], the Flow-Oriented Routing Protocol (FORP) [13] was proposed to get stable routes that have even twice lifetime of the minimum-hop routes [14], but it makes too much hops. So in [15], the author propose the MILET scheme, which cleverly assigns the weight of a link to be 1 plus the inverse of its LET value, and the number 1 represents one hop, thus making the hop number as the weight too.

Two novel routing metrics are proposed in [16]. The first one is Link Occupancy Ratio (LOR), which is used to measure the occupancy level of a link, and the other one is Residual Link Capacity (RLC), it represents accurately how much of additional traffic can the link support. The idea gives us a new proper definition of link quality.

III. MAIN DESIGNING OF ECRMLET

A. Main Idea

When FIB hits, we would calculate LET and available

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probability for each interface in the hit FIB entry, then selecting the best one to be outgoing interface for Interest. The forwarding flow chart is shown in Fig 1.

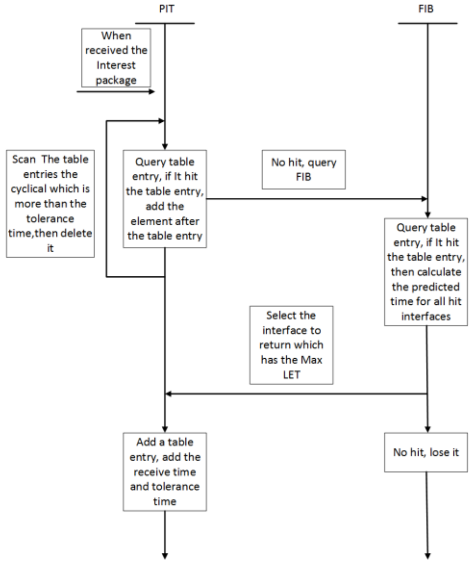

Fig 1. The Forwarding Flow Chart

B. The Designing of PIT

We add two domains of *receive time* and *tolerance time* to PIT, which represent the time of the first Interest arrives and the biggest time of each table entry can tolerant respectively.

We define the *tolerance time* as $2 * \mathrm{TTL}$, and according to the biggest distance and propagation rate, we can get the value of TTL is 3.200s in average, and if a PIT table entry is beyond the *tolerance time*, it would be updated or deleted soon.

TABLE I .THE IMPROVED PIT

prefix	**face**	**receive time(s)**	**tolerance time(s)**
/car1/video/ip3.mp4	6	55.402	6.400
/car5/video/ip2.mp4	5	30.408	6.400

C. LET Algorithm

Nodes need to calculate the LET of each interface in FIB, and the calculation is based on the following prerequisites: our strategy works in a highway environment, where the drive direction of vehicles are parallel, and the transmission range is set as 500m; at time t_0=0, the distance between cars p and q is d; the speed of p and q are v_p and v_q, the accelerations are a_p and a_q; at time t, the distance of the car p and q have traveled are $s_p(t)$ and $s_q(t)$, then there are:

$$s_p(t) = \int_0^t v_p(t) \cdot dt \tag{1}$$

$$s_q(t) = \int_0^t v_q(t) \cdot dt \tag{2}$$

$$v_p(t) = v_p + a_p \cdot t \tag{3}$$

$$v_q(t) = v_q + a_q \cdot t \tag{4}$$

When $\left|s_p(t) - s_q(t) + \mathrm{d}\right| > 500$, the communication between p and q is interrupted, so the LET is the solution of the equation $\left|s_p(t) - s_q(t) + \mathrm{d}\right| = 500$. If there is $s_p(t) - s_q(t) + \mathrm{d} = 500$, which means that p is in front of q; Else q is in front of p. The relative distance between two cars is :

$$s_p(t) - s_q(t) = \left(v_p - v_q\right) \cdot t + \frac{1}{2}\left(a_p - a_q\right) \cdot t^2 \tag{5}$$

We define $v_\Delta = v_p - v_q$ and $a_\Delta = a_p - a_q$,

$$s_p(t) - s_q(t) = v_\Delta \cdot t + \frac{1}{2} a_\Delta \cdot t^2 \tag{6}$$

When there is $s_p(t) - s_q(t) + \mathrm{d} = 500$, we can get:

$$v_\Delta \cdot t + \frac{1}{2} a_\Delta \cdot t^2 + d - 500 = 0 \tag{7}$$

$$\mathrm{t} = \frac{-v_\Delta + \sqrt{{v_\Delta}^2 - 2a_\Delta(d - 500)}}{a_\Delta} \tag{8}$$

Another situation is that $s_p(t) - s_q(t) + \mathrm{d} = -500$:

$$v_\Delta \cdot t + \frac{1}{2} a_\Delta \cdot t^2 + d + 500 = 0 \tag{9}$$

$$\mathrm{t} = \frac{-v_\Delta + \sqrt{{v_\Delta}^2 - 2a_\Delta(d + 500)}}{a_\Delta} \tag{10}$$

Therefore we can get the expression of LET:

$$\mathrm{LET} = \frac{-v_\Delta + \sqrt{{v_\Delta}^2 - 2a_\Delta(d \pm 500)}}{a_\Delta} \tag{11}$$

D. Link Available Probability

According to the paper [17], we can predict the link availability probability as follows:

$$\mathrm{L(t)} \approx \mathrm{p}\{\text{To last to } t_0 + t \mid available\ at\ t_0 + t\} \tag{12}$$

$$\mathrm{E(x)} \approx \mathrm{p}\left\{\text{Epoch length } \leq \mathrm{x} = 1 - e^{-\lambda x}\right\} \tag{13}$$

$\mathrm{L_1(t)}$ represents the probability that the link still exists at time $t_0 + t$, $\mathrm{L_2(t)}$ represents the probability of $\mathrm{L(t)}$.

$$\mathrm{L(t)} = \mathrm{L_1(t)} + \mathrm{L_2(t)} \tag{14}$$

$$\mathrm{L_1(t)} \approx p\{Epoch\ length\ \geq t\} \times p\{Epoch\ length\ \geq t\}$$
$$= e^{-2\lambda t} \tag{15}$$

$$\mathrm{L_2} \approx (2\lambda t)^{-1} + \varepsilon + e^{-2\lambda t}(p\lambda t - (2\lambda t)^{-1} - \varepsilon - 1) \tag{16}$$

$$\mathrm{L(t)} \approx L_1(t) + L_2 \tag{17}$$

$$= (2\lambda t)^{-1} + \varepsilon + e^{-2\lambda \times t}(p\lambda t - (2\lambda t)^{-1} - \varepsilon);\ p = 0.5$$

$$= \left(1 - e^{-2\lambda t}\right) \times \left(\frac{1}{2\lambda \times t} + \varepsilon\right) + \frac{1}{2} \times \lambda \times t \times e^{-2\lambda \times t}$$

Where L represents a collection of content routing of all nodes in network.

$$p(\Delta t) = \begin{cases} 1 - \dfrac{1 - L(t)}{t} \times \Delta t (0 \le \Delta t \le t) \\ \dfrac{L(t)}{\log(\Delta t - t + 1) + 1} (\Delta t > t) \end{cases} \quad (18)$$

Where the $p(\Delta t)$ represents the probability of the content routing L_i still exists at $t_0 + t$ time.

E. Final Decision Making

We set the weight values are both 0.5, and select an interface with the biggest *Final Value*.

$$\text{Final Value} = 0.5 * \text{LET} + 0.5 * p(\Delta t) \quad (19)$$

IV. THE SIMULATION TEST AND ANALYSIS

A. Simulation Set-ups

Our simulation platform is ndnSIM2.0 in NS-3 [18], and the specific parameters settings are shown in table 2.

TABLE II. EXPERIMENTAL PARAMETERS SETTINGS

Environmental parameters	**Value**
Topology	Sprint network
The communication distance	50m
Scope of the environment	1000(m)×1000(m)
The data link type	DLT_IEEE802_11_RADIO
Packet size	1040bytes
Cache size	20
Wireless propagation model	ConstantSpeedModel
Motion model	IDM_LC
Signal attenuation model	FriisPropagationLossModel
RxGain	-10db
The simulation time	100s
Data transmission rate	1Mb/s

B. Results Analysis

1) Transmission Efficiency

We can see TCP/IP has the worst results, and V-NDN is closer to our ECRMLET. It is because TCP/IP takes too much time to find the destination, and our ECRMLET avoids broadcasting and selects optimal outgoing interfaces in FIB.

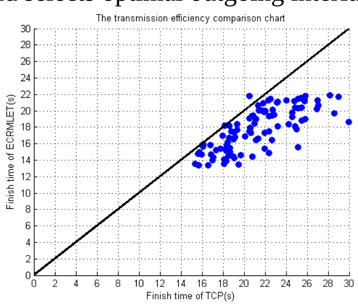

Fig 2. The Transmission Efficiency Comparison with TCP

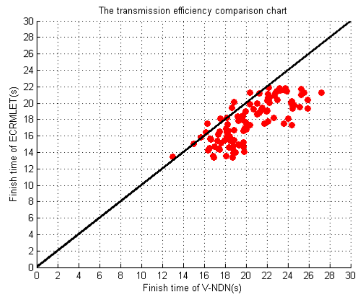

Fig 3. The Transmission Efficiency Comparison with V-NDN

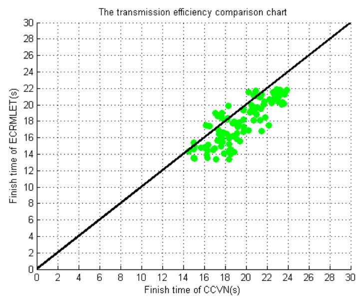

Fig 4. The Transmission Efficiency Comparison with CCVN

2) Response Time

We use the following formula to calculate the average response time:

$$ART_i = \frac{\sum_{j=1}^{i} Time_j}{i} \quad (20)$$

Where the ART_i(Average Response Time) is ART within the first i seconds. $Time_j$ is the response time at the j_{th}s.

As shown in Figure 5, TCP makes no use of any cache, and CCVN has a closer result with our ECRMLET, because in our scheme, the selected paths must be the sub-paths for CCVN and V-NDN, thus their average response time are both bigger than ECRMLET in general.

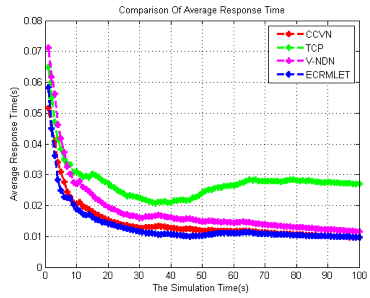

Fig 5. The average response time contrast figure

3) Cache Hit Ratio

From the results, we can see the cache hit ratio of ECRMLET is the highest. We think it is because the selecting process in ECRMLET gets the stable routing paths with a bigger time tolerance, so it can make full use of the network cache.

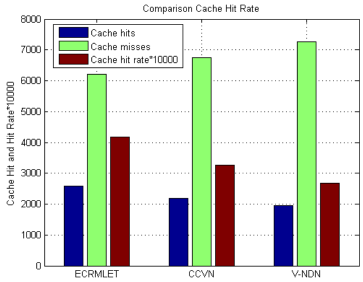

Fig 6. Cache Hit Rate

4) *Network Traffic*

We compare the instantaneous and average network traffic, and average traffic is calculated by the following formula:

$$NT_i = \frac{\sum_{j=1}^{i} nt_j}{i} \quad (21)$$

NT_i is the average network traffic within the first i seconds. nt_j is the network traffic at the j_{th}s.

In Figure 7, we can see the volatility of the V-NDN is the biggest, and our ECRMLET has a more significant decline compared to others. Figure 8 shows TCP has the highest average network traffic, and our ECRMLET has a rapid convergence.

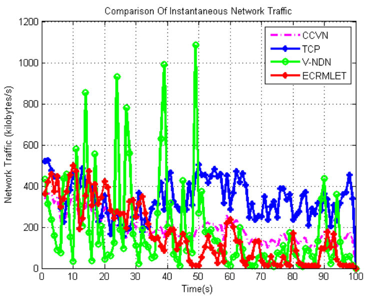

Fig 7. The Instantaneous Network Traffic contrast

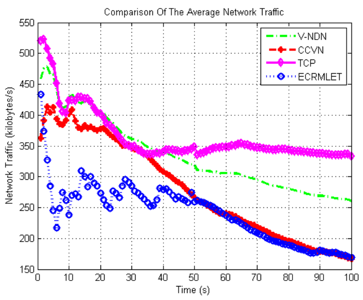

Fig 8. The Average Network Traffic

V. Conclusion

In this paper, as TCP/IP could not adapt well to the high dynamic of VANET, we apply ICN to it, and based on LET and link availability, ECRMLET is proposed to build stable and efficient routings and reduce useless traffic. Simulation results show our ECRMLET gets a better performance than TCP/IP, CCVN and V-NDN.

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