MULTIMEDIA CONTENT DOWNLOADING IN VANET WITH DENSITY MEASUREMENT

E. Lalitha[1], D.Jayachandran[2]

[1]Student/M. Tech, KSR College of Engineering,
[2]AP/CSE, KSR College of Engineering,

ABSTRACT

The development of high end Internet-connected navigation and infotainment systems is becoming a truth that will easily lead to a remarkable growth in bandwidth demand by in-vehicle users. In Examples the applications of vehicular communication proliferate, and range from the updating of road maps to the repossession of nearby points of interest, downloading of touristic information and multimedia files. This content downloading system will induce the vehicular user to use the resource to the same extent as today's mobile customers. By this approach communication-enabled vehicles are paying attention in downloading different contents from Internet-based servers. We summarize the performance limits of such a vehicular multimedia content downloading system by modeling the content downloading process as an effective problem and developing the overall system throughput with density measurement. Results highlight the methods where the Roadside infrastructure i.e., access points are working at different capabilities irrespective of vehicle density, the vehicle-to-vehicle communication.

KEYWORDS

Vehicular ad hoc network, Multimedia content downloading Process, Max-flow problem, and Density measurement.

1. INTRODUCTION

The communication-enabled vehicles are interested in downloading different multimedia contents from Internet-based servers. This system captures many of the entertainment services with effective information, such as navigation maps, news reporting service, and software updating, or multimedia content downloading. In this approach both infrastructure-to-vehicle and vehicle-to-vehicle communication taken place. The major aim is to maximize the overall system throughput; we formulate a max-flow problem that accounts for several practical aspects, such as channel contention and the data transfer paradigm.

As a result, Multimedia content downloading in vehicular networks by the vehicles has received increasing attention from the research community. Initially, the availability of Infrastructure-to-Vehicle (I2V) communication capabilities are based on high-throughput Dedicated Short-Range Communication (DSRC) technologies, is seen as an opportunity for transfer of large data to mobile nodes that would not be possible through the existing 2G/3G infrastructure, Next the availability of Vehicle-to-Vehicle (V2V) connectivity has fostered a number of proposals to make use of the cooperation among vehicular users so as to improve their downloading performance. In particular, V2V connectivity based approaches are especially good when one considers that the infrastructure coverage will be mottled at initial stages, and barely seamless even at later ones.

Previous works on content downloading in vehicular networks have dealt with individual aspects of the process, such as roadside APs deployment, the performance evaluation of I2V communication, the network connectivity, of V2V data transfer paradigms. No one has tried to deal with the problem as a whole, trying to quantify the actual potential of an I2V/V2V-based content downloading process. In order to fill such a gap, we introduce the following questions: (i) *which is the maximum downloading performance achievable through DSRC-based I2V/I2V communication, in a given mobility scenario?* (ii) *What are the important factors that mainly determine such a downloading performance?*

To answer these questions, we combine this downloading process to a mixed integer linear programming (MILP) known as max flow problem. The solution this problem results in the optimal Access point deployment over a given road layout and any possible combination of V2V and I2V data transmission.

Our framework introduces a DTNG time-invariant graph. We do not undertake the contacts between mobile nodes to be same but allow them to access directly, and also report the presence of roadside infrastructure and channel contention. Such an approach allows us to significantly enhance the AP deployment over the given road layout, since we maximize the overall throughput and also provide the optimal solution instead of an approximation.

At the result, the access point or relay shows the vehicle capability prior and sends the corresponding low quality or high quality file. This achieves the vehicle to receive the proper file resource. Vehicle density is calculated based on previous temporal changes and the new vehicle density is calculated. The access points' capabilities are adjusted so that it works more in high vehicle density environment and works less in low vehicle density environment.

This paper is organized as follows: Section II describes the previous work, while Section III discusses contribution of work. In Section IV, we build the system model and assumption, while we generate the Dynamic Network topology graph in Section V and we formulate the max-flow problem in Section VI, Results, derived in the design guidelines described in Section VII. In section VIII, we evaluate the vehicle density based data downloading. Section IX describes Security issues; finally section X summarizes our major findings and point out direction of future work.

2. RELATED WORK

The authors U. Paul, M.M. Buddhikot, A.P. Subramanian, and S.R. Das were stated that the complete measurement analysis of network resource deployment and the subscriber activities using a large-scale data set collected within a nationwide 3G cellular network. The data set keeps close to more number of subscribers over thousands of base stations. They also examine the capability of network resources which can be used by different subscribers as well as by different applications. They also find out the traffic in vehicular network from the point of view of the base stations and analyze the temporal and spatial variations in different kinds of the vehicular network.

In order to address such coverage uncertainties the authors Z. Zheng, P. Sinha, and S. Kumar were given a idea about new the alternating coverage for mobile users, called α-coverage, and examined how such coverage can be attained by systematic deployment of more APs to create an efficiently scalable infrastructure. In other way, a deployment of APs involved in α-coverage to a network topology, if the road with length α on the given network resource meets with at least one AP in that resource.

The authors Z. Lu, Z. Zheng, P. Sinha, and S. Kumar were also stated that with increasing popularity of media enabled devices; the need for high data-rate services for mobile users is obvious. Large-scale Wireless LANs (WLANS) can offer such a service, but they are very expensive to deploy and maintain. The above results not make the grade to provide any throughput assurance to a vehicular user; it can only provide opportunistic services to them.

3. MY CONTRIBUTION

The density measurement in vehicular network my contributions to this problem are as follow:

- The access point or relay tracks the vehicle capability prior and sends the corresponding low quality or high quality file. This achieves the vehicle to receive the proper file resource
- Vehicle density is calculated based on previous temporal changes and the new vehicle density is calculated.
- The access points' capabilities are adjusted so that it works more in high vehicle density environment and works less in low vehicle density environment.
- Vehicle density based download scenario is applied to Access Points.

Proposed methods where the Roadside infrastructure i.e., access points are working at different capabilities irrespective of vehicle density.

4. SYSTEM MODEL AND ASSUMPTIONS

4.1. Network Model

We create a network composed of fixed roadside APs and vehicular users, where some of them are downloader's. They are interested in downloading multimedia content from the Internet through the APs. We consider the general case in which every downloader may be interested in different content. They can either use relays or establish direct connectivity with APs. In particular, we consider the following data *transfer paradigms*:

Direct transfers, a direct communication between an AP and a downloader. This shows the typical way how the mobile users communicate with the infrastructure as in today's wireless networks;

Connected forwarding, the result shows communication made through one or more vehicles that create a multi hop path between an AP and a downloader. This is the conventional approach to traffic delivery in ad hoc networks;

Carry-and-forward, the communication made through one or more vehicles that store and carry the data, and delivering them either to the target downloader or to another relay which meet such downloader sooner.

Our approach allows us to processing a road layout and an associated vehicular mobility trace, so as to build a time expanded graph that represents the temporal network evolution (Sec. V). By using this graph, we formulate a max-flow problem; the solution of this problem matches our goals.

5. DYNAMIC NETWORK TOPOLOGY GRAPH

Dynamic network topology graph (DNTG) generate a from a different vehicular mobility trace in network topology, considering that on the corresponding road layout there are: (i) a set of A candidate locations (i = 1, . . . , A) where APs could be placed (ii) a set of V vehicles (i = 1, . . . , V) travel over the road layout (iii) a set of D vehicles that wish to download data from the APs.

The major aim of this topology graph is to model all possible ways through which data can flow from either direct APs to the downloader's or possibly via relays. With known mobility trace, we identify the *contact events* between any pair of nodes such as V2I/V2V.

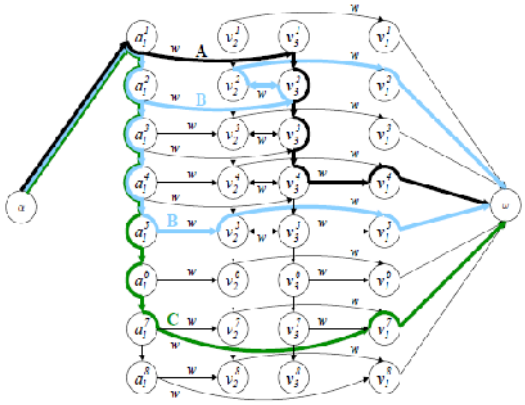

Figure1. A sample DNTG, with one Access point A and three vehicles v1, v2 & v3, the vehicle (v1) is a downloader while the others (v2, v3) can act as relays. In the above graph, we show up paths that are agent of the carry and-forward (A), connected forwarding (B), and direct transfer (C) paradigms.

Each contact event is characterized by:

- Link quality, The quality of the link between the two nodes; specifically, the achievable data transfer rate at the network layer, which depends on the distance between the possible two nodes
- The contact starting time, The time at which the link between the two nodes is established or already established link that has quality level with new value;
- A contact ending time, the time at which, the quality level of link has changed when the link is removed or discarded

The time interval between any two contact events in the network is called *frame*. Within a frame the network is static, which means no link is created or removed and the link quality levels do not change. We denote the number of frames in the considered trace by F, and the duration of the generic frame k (1 ≤ k ≤ F) by k; also, all on-going contact events during frame k are said to be *active* in that same frame.

Each vehicle V_i participating in the network at frame k is represented by a vertex V_i^k (1 ≤ i ≤V) in the DNTG, where as each candidate AP location A_i is mapped within each frame k onto a vertex A_i^k(1 ≤ i ≤ A). We denote by V^k and A^k theset of vertices representing, respectively, the vehicles and APsin the DNTG at time frame k, while we denote by $D^k \subset V^k$the subset of vertices

representing the downloaders that existin the network at frame k. All non-downloader vehicles in$R^k = V^k \backslash D^k$can act as relays, according to the data transfer paradigms outlined above.

Within each frame k, a directed edge (V_i^k □ V_j^k) exists fromvertex V_i^k □ R^k to vertex V_j^k □ V^k if a contact between thenon-downloader vehicle V_i and another vehicle$V_j$is active during that frame. Each edge of this frame type is associated with a weight w (V_i^k , V_j^k), equal to the rate of that corresponding contact event. The set including such edges is defined as L_v^k .

Similarly, a directed edge (A_i^k ,V_j^k) comes from vertex A_i^k □ A^k to vertex V_j^k □ V^k if a contact between the candidate Access point Ai and the vehicle V_j is active during frame k. Again, these edges are associated with weights w (A_i^k , V_j^k), equivalent to the contact event rate, and their set is defined as L^k a. A directed edge (V_i^k, V_i^{k+1}) is also drawn from any vertex V_i^k □ R^k to any vertex V_i^{k+1} □ R_i^{k+1}, for 1 ≤ k ≤ F. While the edges in L_v^k and L_a^k represent transmission opportunity, those of the form (V_i^k,V_i^{k+1}) model the possibility that a nondownloader vehicle $V_i$physically carries some data during its association from frame k to frame k + 1. Accordingly, these edges are associated with a weight representing the vehicle storage capabilities, since they do not involve any rate-limited data transfer over the wireless medium. However, dealing with vehicular nodes as conflicted to resource-constrained hand-held devices, we take the weight of such edges to be assume on an infinite value. A directed edge (A_i^k, A_i^{k+1}) of infinite weight is also drawn between two any vertices representing the same candidate AP at two consecutive frames, i.e., from $A_i^k \epsilon A^k$ to $A_i^{k+1} \epsilon A^{k+1}$ (1 ≤ k ≤ F). We will refer to the edges of the kind (V_i^k, V_i^{k+1}) or (A_i^k , A_i^{k+1}) as intra-nodal.

Finally, in order to originate a max-flow problem over the DNTG, we introduce two virtual vertices, □and ω, respectively representing the source and destination of the total flow of the graph. Then, the graph is finished with infinite weight edges (□, a_1^i), from □ to any vertexa_1^i □ a_1 , and (V_i^k, ω), from any vertex $V_i^k \epsilon D_k$to ω, 1 ≤ k ≤ F.

The DNTG is therefore a weighted directed graph, representing the network topology development over time. An example of DNTG is given in Fig. 1, in presence of one AP and three vehicles v1, v2,& v3, with v1 being a downloader and v2, v3 possibly acting as relays. There, contact events divide different frames that correspond to rows of vertices in the DNTG, where intra-nodal edges connect vertices which represent the same vehicle or candidate Access point over time. To minimize the graph size, in this example we assume the achievable network-layer rate w to be constant during the complete lifetime of a link; in our performance evaluation, instead, we consider a more complex model, which accounts for pragmatic variations of the rate as a function of the distance between the two nodes. And also, note that the graph allows the capture of all the data transfer paradigms previously discussed. It is thus possible to identify paths in the graph that correspond to (1) direct download from the Access point to the downloader, as path C, (2) connected forwarding through 3-hops (frame 2) and 2-hops (frame 5), as path B, and (3) carry-and-forward through the movement in time of the relay vehicle v3, as path A.

6. THE MAX-FLOW PROBLEM

With specified DNTG, our next step is the formulation of an optimization problem whose goal is to maximize the flow from □ to ω, i.e., the total amount of downloaded data by the downloader's. Denoted by x (V_i^k, ω) the traffic flow over an edge connecting two generic vertices, our intention can be expressed as:

$$max \sum_{k=1}^{F} \sum_{V_i^k \in D^k} x(V_i^k, \omega). \qquad (1)$$

The max-flow problem needs to be solved taking into account several constraints for e.g., non negative flow and flow conservation, maximum number of APs that can be activated, and channel access. We detail such constraints below.

A. Constraints

Non-negative flow and flow conservation: the flow on each existing edge in DNTG must be greater than or equal to zero. Also, for any vertex in the graph, the amount of flow entering the vertex must equal the amount of outgoing flow.

Channel access: In view of the fact that we consider an IEEE 802.11-based MAC scheme with RTS/CTS and we assume unicast transmissions, two or more of the following events cannot take place simultaneously for a tagged vehicle, and the time duration of each frame must be shared among the tagged vehicle:

1) The vehicle transmits to a neighboring vehicle;
2) A neighboring vehicle receives from any relay;
3) The vehicle receives from a neighboring relay;
4) A neighboring relay transmits to any vehicle;
5) The vehicle receives from a neighboring AP;
6) A neighboring AP transmits to any vehicle.

Here, we only consider the total amount of data carried by each flow. Due to the use of RTS/CTS in 2) a neighboring vehicle receiving data is accounted, considering that: 1) is a sub case of 2); 3) is a sub case of 4); 5) is a sub case of 6), for the generic vertex $V_i^k \epsilon V^k$ and for any frame k, we have:

$$\sum_{\substack{V_j^k \varepsilon R_{,}^k V_m^k \epsilon V_m^k \epsilon V^k \\ (V_j^k, V_m^k) \epsilon L_v^k}} 1\left[\left(v_m^k, v_j^k\right)\right] \frac{x\left(v_j^k, v_m^k\right)}{x\left(v_j^k, V_m^k\right)} + \sum_{\substack{V_j^k \varepsilon R_{,}^k V_m^k \epsilon V_m^k \epsilon V^k \\ (V_j^k, V_m^k) \epsilon L_v^k}} 1\left[\left(v_j^k, v_i^k\right)\right] \frac{x\left(v_j^k, v_m^k\right)}{x\left(v_j^k, v_m^k\right)} +$$

$$\sum_{\substack{V_j^k \varepsilon R_{,}^k V_m^k \epsilon V_m^k \epsilon V^k \\ (V_j^k, V_m^k) \epsilon L_v^k}} 1\left[\left(a_m^k, v_j^k\right)\right] \frac{x\left(a_j^k, v_m^k\right)}{x\left(a_j^k, v_m^k\right)} \leq \tau^k \qquad (2)$$

Where the indicator function is equal to 1 if the specified edge exists, and it is 0 otherwise. In addition, for each candidate AP, we have that its total transmission time during the generic frame k cannot exceed the frame duration. Thus, for any k and $A_j^k \epsilon A^k$, we have the equation as:

$$\sum_{V_i^k \in V^k (a_j^k, v_i^k) \epsilon L_a^k} \frac{x\left(a_j^k, v_m^k\right)}{x\left(a_j^k, v_m^k\right)} \leq \tau^k \qquad (3)$$

The above constraints allow a vehicle under coverage of an AP to use I2V and V2V communication within the same frame. Next, we consider the case where a vehicle under the

coverage of either one AP is not configured to work in ad hoc mode, i.e., the communication with other vehicle is not possible. Then, for every frame k and V_j^k □ R^k,$V_m^k \epsilon v^k$ such that (V_j^k, V_m^k) □ L_v^k, the following constraint holds:

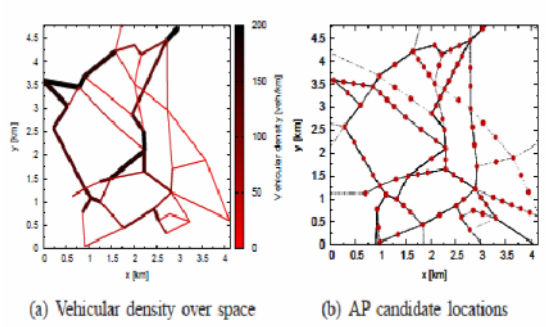

Figure2. Simulation scenario: (a) road layout and average density of vehicles computed over a whole day; (b) giving out of the AP candidate locations over the road layout.

$$x(v_j^k, v_m^k) \leq \left(1 - \max_{\substack{a_i^k \in A^k \\ (a_j^k, v_i^k) \epsilon L_a^k}} \{y_i\} \right) w(V_j^k, V_m^k) \tau^k \quad (4)$$

Wherey_i, i = 1 . . . A, are Boolean variables, whose value is 1 if the candidate AP A_i is activated and the value becomes 0 otherwise.

Maximum number of active APs: The final set of constraints imposes that no more than one candidate APs are selected, through the variablesV_i. Then, for any i, we can write:

$$y_i \text{ □ } \{0,1\} ; \sum_{i=1}^{A} y_i \leq \hat{A} ; x(\propto . a_i^1) \leq M y_i$$

Where M ϵ R is a randomly large positive constant.

7. DERIVING DESIGN GUIDELINES

We influence the problem formulation obtained in the previous section to illustrate which factors concern the most in content downloading process in vehicular networks and to provide realistic hints for the design of a system. We consider a real-world road topology, covering an area of 10 km2 in the urban area. The vehicular mobility trace in the region has been synthetically generated at urban area, through a multi-agent microscopic traffic simulator. In Fig. 2(a), we describe the road layout which explains the different traffic methodology observed over each road layout.

We consider a traditional VANET technology penetration rate, which means that only a fraction of the vehicles in the network, namely 20%, is equipped with a communication interface or communication device and is ready to participate in the content downloading process, either as relays or as downloader's. Also, the number of vehicular downloader's that concurrently request content is assumed to be 1% of the vehicles participating in the network. AP locations are selected along the roads such that the distance between two adjacent APs is slightly equal to 150

m, resulting in 92 candidate locations, shown in Fig. 2(b). The value of the achievable network-layer rate between any two nodes is attuned according to the distance between them. We bounded the maximum node transmission range to 200m; this distance allows the establishment of a reliable communication in 80% of the cases.

Since we make use of a realistic mobility model, in each road topology the intensity of the vehicular traffic varies depending on the road segment and time period of the day. In Fig. 3a, 3b, and 3c, we describe the road layout of the urban, village, and suburban village environments, stress the different traffic volumes observed over each road segment: Thicker, highlighted density segments identify the roads layout characterized by higher vehicular density. As far as vehicular traffic variations in given road layout is concerned, we consider only time periods corresponding to the density of vehicles.

In the urban, village, and suburban road layout traces, each enduring about 6 hours, this leads to an average density of 90, 62.5 and 33.5 veh km, respectively. The value of the attainable network-layer rate between every two nodes is adjusted according to the distance between them. To this end, we refer to the 802.11a experimental results that obtain the values shown in Fig. 3d, and we use them as samples of the achievable network-layer rate. Note that we ends up the maximum node transmission range to 200 m, because, this distance allows the establishment of a reliable communication in 80 percent of the cases.

Given that Aˆ locations have to be activated, the result of the max-flow problem in Sec. 4 provides the AP deployment that maximizes the aggregate download throughput. We benchmark the performance of our optimal Max-flow strategy against the following AP deployment policies:

Random: According to a uniform distribution, APˆ locations are randomly selected among the candidate.

Crowded: It selects the APˆ locations whose coverage area exhibits, above the highest vehicular density;

Contact: It picks up the APˆ locations that maximize the addition of the contact opportunities between vehicles and APs.

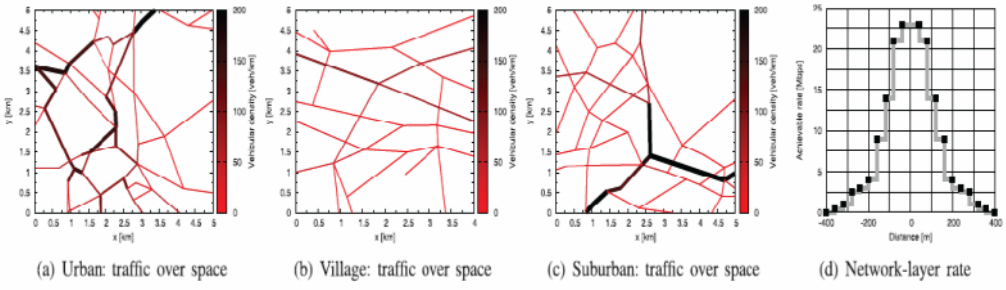

Figure3. Road layout in the (a) urban, (b) village, and (c) suburban scenarios, and achievable network-layer rate characterization as a function of distance (d).

Particularly, for each vehicle, the contact opportunity is expressed as the fraction of the road section lengths traveled while under coverage of at least one AP. Once the active AP locations in the given road layout are determined according to any one of the above three policies, they are

used in the max-flow problem formulation to secure the values of the binary variables yi. Since the system throughput is obtained as the result of the max-flow problem with the preferred AP locations yi, the results we show represent the preeminent performance one can achieve with each deployment strategy. Fig. 3 shows the average content downloader throughput for different deployment strategies, with the function of the number of active APs Aˆ.

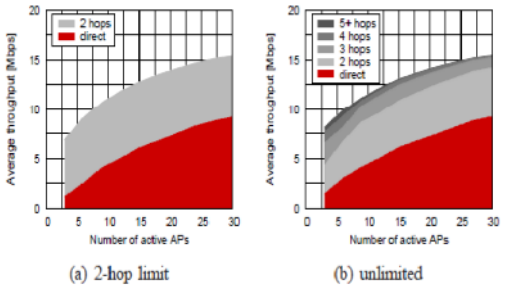

Figure4. Partition of the average downloader throughput with respect to the number of relays between AP and downloader (Max-flow deployment strategy)

In order to demonstrate the absolute result of the throughput figures reported above, we focus on the Max-flow deployment strategy and look at the number of hops that data go through before reaching their destination. In Fig. 4(a), the hop limit is set to 2 which means the number of relays between APs is 2, thus the plot in the above graph describes the portion of the average per downloader throughput is due to direct data transfers and which is instead reached using one relay, when the number of deployed APs is small then the last hop largely dominates the previous hop. As the existence of APs becomes more pervasive, direct transfers paradigm are clearly more frequent. However, it is most important to observe that the amount of data downloaded through one relay remains constant, even when 25 APs covering 50% of the road layout are deployed. The proportion of throughput achieved through direct and multi-hop data transfers does not change when the boundary on the number of allowed hops is removed, in Fig. 4(b). There, we can also note the small contribution due to transfer's over 3 or more hops, specifically for 10. Finally, the comparison between Fig. 4(a) and Fig. 4(b) shows the complexity due to the use of more than one relay at a time can be eliminated without significant destruction. To summarize, we illustrate the following conclusions:

- Traffic relaying, through either connected forwarding or carry-and-forward, can considerably increase the average per-downloader throughput, even when the road layout is covered by more APs;
- Multi-hop data transfers involving more than one relay are less beneficial to the content downloading process.

8. VEHICLE DENSITY BASED ACCESS POINT DATA DOWNLOADING

In addition, the access point or relay tracks the vehicle capability prior and sends the corresponding low quality or high quality file. This achieves the vehicle to receive the proper file resource.

Vehicle density is calculated based on previous temporal changes and the new vehicle density is calculated. The access points' capabilities are adjusted so that it works more in high vehicle density environment and works less in low vehicle density environment.

9. SECURITY ISSUES

9.1 Digital signatures as a building block

The message authenticity is necessary to protect VANETs from outsiders. But since safety messages will not contain any sensitive information confidentiality is not required. In this system, the exchange of safety messages by vehicles in a VANET needs authentication of message but no need for encryption of such message. Symmetric authentication mechanisms usually encourage less overhead per message than their asymmetric counter parts. In the VANET setting, safety messages are typically standalone and should be sent to receivers as quick as possible so the digital signatures are a better choice. In fact, a preface handshake is not suitable and actually creates more overhead. In addition, with the huge amount of network participants and the irregular connectivity to authentication servers, a PKI (Public Key Infrastructure) mechanism is the most suitable method for implementation of message authentication.

9.2 Estimation of the signature size

As we intend using a PKI for supporting security in VANETs, it is significant to choose a Public Key Cryptosystem (PKCS) with a tolerable implementation overhead in the vehicular network. According to DSRC, safety messages are sent with a periodicity of 100 to 300 ms. this inflict an upper bound on the processing time overhead; this overhead is shown below:

$$Toh(M) = Tsign(M) + Ttx(M\ SigPrKV\ [M]) + Tverify(M)$$

Where Tsign (M), Ttx (M), and Tverify (M) are the necessary time durations to sign, transmit, and verify a message M, respectively; SigPrKV [M] is the signature of M and also includes the CA's certificate of the signing key by the sending vehicle V. The above expression shows the three factors that affect the choice of a particular PKCS: (1) the execution speeds of the signature generation (2) the verification operations, and (3) the sizes of key, signature, and certificate.

Since the actual size of encrypted messages is between 100 and 200 bytes, before being signing, the message is hashed. The overhead is almost constant for a given cryptosystem.

Hence, it is possible to evaluate different options at least relatively to each other .In fact, there are more number of candidate PKCS for implementing the PKI in a VANET. To ensure the future security of the PKCS, and taking into account the deployment schedule of DSRC.

Table 1: Size and transmission time of PKCS

PKCS	Sig size(bytes)	T_{tx}(Sig)(Ms)
RSA	256	0.171
ECDSA	28	0.019
NTRU	197	0.131

Table 2: Comparison of signature generation and verification times on a memory-constrained Pentium II 400 MHz workstation

PKCS	Generation(ms)	Verification(ms)
ECDSA	3.255	7.617
NTRU	1.587	1.488

We list records for public key and signature sizes:

1. RSA Sign: the key size and signature sizes are large (256 bytes).
2. ECC (Elliptic Curve Cryptography): it is smaller than RSA (28 bytes), slower in verification but faster in signing.
3. NTRU Sign4: the key size is lies between the RSA and ECC (197 bytes), but in both signing and verification. it is much faster than the RSA and ECC

In DSRC the least data rate is 6 Mbps (for safety messaging data rate is typically 12 Mbps), the transmission overhead (at 12 Mbps) is acceptable, and these two options are shown in Table 1 and Table 2 gives approximate execution times of signature generation and verification for ECDSA (Elliptic Curve Digital Signature Algorithm) and NTRU Sign. These figures in the table should be taken only as suggestive for the specific platform such as Pentium II 400 MHz with memory constraints.

In conclusion, we can observe that in terms of performance, ECDSA and NTRU outperform RSA. Compared to each other, the advantage of ECDSA is its small and economically designed; whereas NTRU's is more speed than ECDSA. The result should depend on case-specific evaluations.

10. CONCLUSION

We examined the main factors affecting the performance of content downloading process in vehicular networks, by formulating and solving a max-flow problem over a time extended graph representing a realistic vehicular trace.

The important results in our system are as follows:

- Our major ideas are that a density-based AP deployment yields performance close to the optimum result, and that multi-hop traffic delivery is valuable, although the gain is negligible beyond 2 hops from the AP.
- The access points' capabilities are adjusted so that it works more in high vehicle density environment and works less in low vehicle density environment.

To our best knowledge, this paper addressing the security of vehicular networks in a efficient and quantified way.

In terms of future work, we aim to further develop this proposal. In particular, we plan to explore in more detail the respective merits of key distribution by the manufacturers or by legislative bodies; we will also going to carry out additional numerical evaluations of the solutions.

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