Virtual Access Points for Stream Based Traffic Dissemination

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Abstract—**In this paper we consider the problem of dissemination of stream based traffic using Access Points as Roadside Equipment. We consider how areas outside direct coverage can still be reached by means of other vehicles acting as Virtual Access Points (VAPs). The developed technique, allows transparently extending the reach of roadside access points to uncovered road areas. VAPs are designed to avoid interference, operating in regions bounded outside any AP. The simulations show the presented mechanism to exhibit gain, in terms of received messages, of 30% and perhaps more significantly, that streaming data delivery becomes feasible.**

Index Terms—**Virtual Access Points, wireless networks, mobile networks, data streaming.**

I. INTRODUCTION

In the future, pervasive wireless world, all roads and cities may be covered by roadside base stations and access will be provided to both pedestrians and vehicular users. However, for the moment, road side equipment or Access Points (APs) are not always present, resulting to uncovered areas where the only possible communication mode is from one vehicle to another. Furthermore, equipping each new generation of networking access devices requires time to be deployed in large scale. User equipments are easier to update and will often have more capabilities than the roadside infrastructure. This paper discusses a simple, yet powerful, technique to extend coverage to nodes outside covered areas. We focus on streaming data dissemination through Virtual Access Points (VAPs), extend [10] focusing on streaming traffic and applie the VAP concept in a city environment. We discuss how, and to what extent, VAPs can enable streaming on a highway or a city environment.

Using VAPs allows us to increase the coverage of the real APs through the help of mobile nodes. These nodes coordinate to increase network coverage area. The mobile nodes can cache messages originating from the APs, and act as VAPs to other nodes in non covered areas. Thus, the nodes, collaboratively, help to forward packets to areas previously uncovered and unused. Figure 1 and Figure 2 demonstrate typical histograms of messages received in a 2Km simulated square of Washington DC and a highway segment respectively. Observe that VAPs provide a much more homogeneous and less intermittent distribution extending the areas where mobile nodes receive messages. The VAP technique was first designed to be used in road like

environments, but as shown in Figure 1 metropolitan environments can too benefit from it.

The rest of the paper is organized as follows; Section 2 discusses related work, whereas Section 3 formulates the proposed solution and outlines our analysis. Section 4 presents the simulations results, and, finally, concluding remarks and future research are given in Section 5.
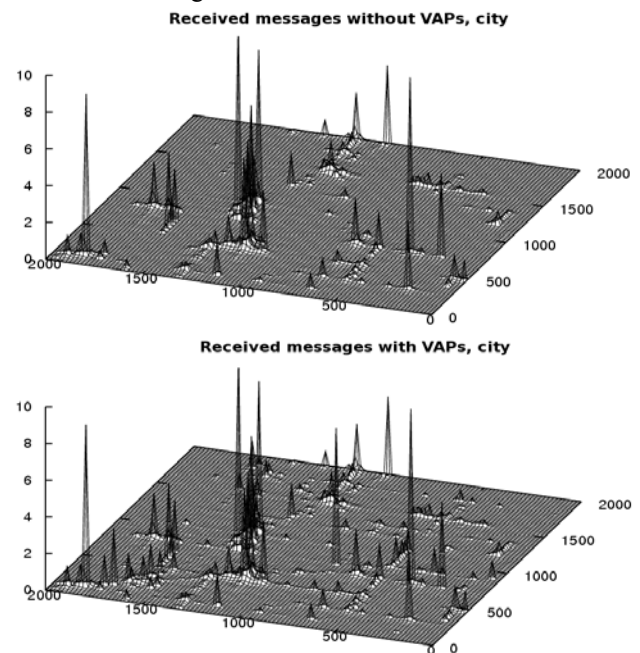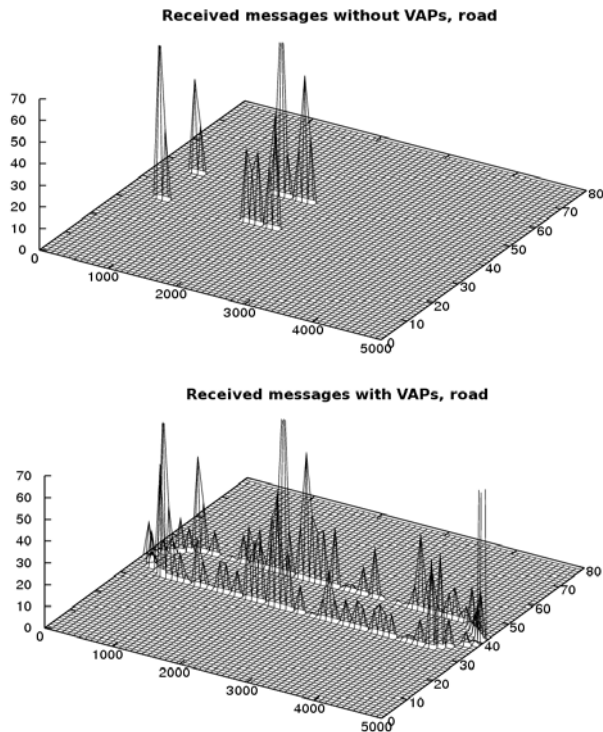

Figure 1 - Typical receiving messages map for a 50 APs city scenario, we can see how VAPs allow us to connect existing "connectivity isles"

II. RELATED WORK

Data dissemination is a key issue in any network, and has been well studied. It is push-based when the data are repeatedly broadcasted in a cycle; pull based when it is explicitly requested by the users; and hybrid when using a mixed push-pull approach. Push or push-pull based delivery is attractive in many systems and has been well studied [11,12,13]. Environments of mobile users with deadlines are discussed in more recent papers [14,15].

Vehicular communications constitutes an especially active area. Various techniques and target applications have been studied. Most of them target the problem of improving safety through the use of wireless networks. Therefore, many

proposed techniques prioritize critical messages while allowing non critical applications to utilize overhead bandwidth. The system considered uses overhead bandwidth for delivering streaming data, often requested by more than one user. The network architecture followed here is based in the basic multiple Infostation model [4], However, we will refer to the Infostations as Access Points (APs).

Figure 2 - Typical receiving messages map for a 5 APs highway scenario

This work aims to extend access to areas out of AP coverage. In the same line, the SPAWN, introduced by Gerla et al. in [1],[2], where it is discussed how vehicles should interact to accommodate swarming protocols, such as BitTorrent traffic. In SPAWN, the nodes passing through APs collect data that they subsequently exchange among nearby nodes. SPAWN focuses on a restricted application that generates great volumes of traffic. Nodes are often required to carry traffic useless to them and the BitTorrent protocol is bandwidth intensive. Moreover, the number of retransmissions of a message in a vehicular network is estimated to be approximately 3 and so our gain from using the swarming protocol in this environment is non-optimal.

The Data Mule project [3] and the Message Ferrying scheme [1], designed for sensor networks, propose the use of mobile nodes to collect data from the sensors, buffer it, and deliver the collected data to a sink. As opposed to these works, we consider the problem not of retrieving data from the nodes, but of disseminating it to them. Our goal is not to build a full delay tolerant system, but merely to extend the capabilities of existing APs with the use of VAPs [10]. The MULEs (Mobile Ubiquitous LAN Extensions) and ferries utilize nodes navigating through the sensor network to collect data in "mobile caches". According to the Data Mule project, all the nodes are fixed and only the cache is mobile. In contrast, in our scenario all nodes are mobile but we cannot affect their trajectories. Message Ferrying also considers mobile nodes but in that approach, as well as in [6] and [7], the nodes are required to follow specific paths and even move in order to help message delivering. The work presented in [7] proposes a multicast protocol for the highway environment where information dissemination though message flooding for VANET environments is proposed. Our proposal advocates using of a more systematic approach for data dissemination, which is more bandwidth efficient.

Chen et al. [5] study network delay as a function of the number of cars and their velocity. The authors note that node mobility on highways can improve end-to-end transmission delay when messages were relayed. Furthermore, that low density networks may experience higher delays. These results are directly related to our work. VAPs locations should be selected so that information is not too widely spread and messages of time sensitive applications can reach their destinations in time.

An appealing solution to the problem, but more expensive and probably harder to implement, is the system proposed by Gavrilovich in [8]. In this work, to compensate for the velocity of the cars, the authors propose the creation of a chain of mobile APs on the center of the highway. Their role is to increase coverage and compensate for the high velocity of cars on the highway.

III. VIRTUAL ACCESS POINTS FOR MOBILE NODES

A. Protocol

The main focus of the Virtual Access Point's technique is to decrease the areas not covered by roadside APs so as to minimize the problem of intermittent access to mobile nodes. If we are able to decrease this problem, then stream traffic for mobile users may be enabled.

Each node, after receiving a message, caches it and can in future become a VAP, acting similarly to a relay node. Note however that instead of just resend the messages the VAP, stores the message and may send it more than once or not at all depending on the caching strategy and depending on the locations it will pass by. VAPs strive to supplement the lack of real APs in a given area broadcasting messages received previously from other AP or even VAPs. A node acts as a VAP if it is not in range of neither an AP nor a VAP and its distance from the nearest AP is $2r$, where r denotes the AP transmission range. This in practice means that nodes are allowed to act as VAPs only when it is in a distance where its MAC layer does not detect any APs above a very low SNR. We also assume that the MAC layer resolves conflicts to the medium access.

In case a node senses another node acting as VAP in the same region, it gives up being a VAP, even if it lies in the area it could act as one. Therefore, the first node to broadcast VAP messages in a given region becomes the VAP . Nodes are not allowed to act as VAPs during two consecutive time intervals. Figure 3 shows a typical scenario where a vehicle (A) acts as VAP providing access to vehicle (C). In turn, vehicle (D) will

transmit the information it just received from the AP when it reaches the same area.

B. Analysis

The data stream is generated in a constant bit rate (CBR). At each second 1, 2 or 3 packets are generated from a source and spread through all antennas, which are then in charge of broadcasting the stream message to their neighbors. Each message is transmitted from each antenna just once. Every mobile node has a limited size buffer where it stores the last received messages. During cache replacement the oldest stream message, with lower stream ID, is discarded first, regardless it was the last one to be received or not.
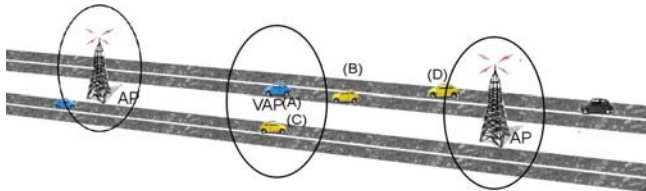

Figure 3 - A road coverage vision

The system is a best effort one; there are no guarantees that every node will receive all stream packets, but using VAPs, we aim to increase the chances for timely reception. Note that the VAPs increase significantly the overall number of messages in the network; however, this increase occurs in areas with no previous coverage, so they create no significant interference with the normal network behavior. The increase in the number of messages sent is upper bounded by:

$$\#IncreasedMessgs \leq nEM = nVAP * BS \quad (1)$$

Where #IncreasedMessgs is the number of exchanged messages, nEM is the maximum number of exchanged messages, nVAP is the number of Virtual Access points, and BS is the cache Buffer Size. Unfortunately not all received messages are useful for every node and the duplicate or old objects are discarded. The number and locations of the VAPs will greatly affect the system's performance. onsequently, the role of VAP is assigned dynamically. Based on the node's mobility pattern and distance from any APs, the nodes autonomously decide if they should act as a VAP.

We formally verified [9] the VAP protocol behavior prior to each simulation. Our aim was to verify whether the protocol is loop free or not. Surprisingly we found a number of situations where loops may occur. For example, considering Figure 3, the simplest loop scenario occurs in the following case: node (A), acting as VAP, transmits the message M1 that is received by the node (B). Considering node (B) faster than node (A) and starting to act as a VAP in an ahead point in the road, it can transmit message M1, that if received by node (A) would characterize a loop. For this reason messages need to be equipped with unique IDs. Once the node (A) receives a duplicated message, identified by the ID, the node discards the message, indeed preventing the loop formation.

Another type of message loop is present, and in fact is even desirable. Again, let us consider Figure 3; supposing the node (A) acts as a VAP in the lane 1, the message M1 sent can

reach the node (C), going in the opposite direction in the lane 2. At some point in the future the node (C) start to act as a VAP and retransmits the message M1 that is received by the node (D) in the lane 1. If node (D) does not have the message, it is stored and will be retransmitted in the future in case node (D) becomes a VAP. However notice that this case is not a loop in the conventional sense, since the nodes involved are different. Another point to observe is that this kind of loop is even desirable since it helps spreading messages over the region. The buffer favors newer messages, so when older messages will be ignored and removed from the buffer.

Even though the VAPs do not transmit when they find out there is other VAP in the same area, depending on the MAC layer protocol used, concurrent transmissions and hidden/exposed nodes problems may also occur. Here we consider the existence of a MAC layer mechanism to handle this, e.g. scheduler for IEEE 802.16 networks or CSMA/CA for IEEE 802.11 networks. However if collisions occur, then the worst impact will be a waste of bandwidth in a region that was not previously in use by any way.

We also found out that there may exist nodes in the network that never take advantage from the VAPs technique. There is no guarantee the mobile nodes will receive all the messages needed to fill their buffers, or a node traverses the entire path from one AP to the other without receiving any message from other VAPs. This will happen if the node is unfortunate enough so as to not be inside the VAP range of other nodes acting as VAP, or when the node itself is acting as VAP for others, and thus is not receiving messages from other VAPs. These situations are more likely to occur in sparse networks.

IV. SIMULATIONS

We examine two types of environments: a highway segment and a city section. The highway segment considered is 5Km long having four lanes, two in each direction with cars going back and forth on it. For the city environment we chose a $2km^2$ area of Washington DC city center as mapped by the Topologically Integrated Geographic Encoding and Referencing (TIGER) system with cars distributed through it. For each scenario we have 40 different configurations of 10 simulation minutes, with 200 vehicles and a transmission range of 100m. Nodes in the city environment have minimum speed 18Km/h and maximum limited by each road's speed limit as registered to the U.S. Census Bureau. For the highway environment the vehicles minimum and maximum speeds are 60Km/h and 110 Km/h respectively. The scenarios follow a realistic mobility pattern generated with the VanetMobiSim [11] tool. Each generated scenario has a number of APs placed randomly. All data is presented with a five percentile and confidence interval of 99%. All simulations keep the same basic configuration and one particular parameter is varied. Variant parameters are: the stream transmission rate, the number of static APs and the method VAPs select messages to re-broadcast. The source of the stream generates CBR traffic from 1 to 3 messages per second. The number of APs tested for the city environments where 2, 25, 50 and 100. For the highway environment the number of APs evaluated where 2,

5, 10 and 15. The three ways the VAPs messages are chosen are random, oldest message first and newest message first.
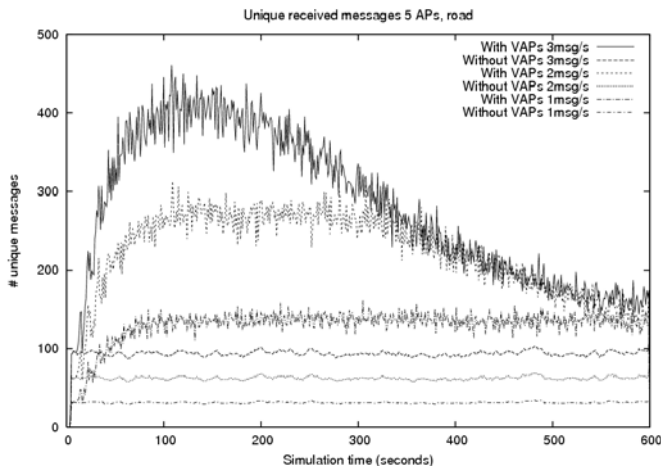
Figure 4 – Unique received messages through the 10 mins of simulation for the highway environment with different traffic rates

We used Sinalgo, the simulation framework for testing and validating network algorithms developed in Java by the Distributed Computing Group at ETH Zurich.

VAPs were first devised for highway environments. This work extends the technique and tests it in city environments. As Figure 4 and Figure 5 shows, it is valuable in both scenarios. Figure 4 demonstrates the behavior of the VAPs for a highway environment displaying the number of unique messages received. Unique messages are defined as messages received by a mobile node for the first time. Numbers of unique messages start to decrease around the 200s because at this point the caches of the nodes start saturate with stream messages and diversity of messages among the nodes caches decreases. This does not occur as much in the city environment as it does in rural environment of the simulated scenarios. In the highway scenario the cars perpetually move along the two opposite highway directions. Thus, the nodes exchange more messages but of decreased diversity. In the city environment, however, nodes follow dissimilar paths which results to diverse cache contents. The number of lost messages decreased between 10% to 15% for city environments while for the highway environment it decreased between 10% and 27.88%.

Figure 6 shows the difference of having 2 or 25 APs in the city scenario for varying bit rates. Both the number of APs, and the bit rate, influences the number of unique messages received in total. However, as expected, the number of unique messages for scenarios where VAPs are not present is nearly constant, as it only depends on the nodes passing near the APs. Even when the bit rate increases we do not observe a significant increase in the number of unique received messages. When bit rates are increased from 1 to 3 packets per second, in the 2APs case, the result is marginal. When VAPs are enabled, unique messages received significantly increase, because 2 antennas are not enough to spread the information through the entire network. The VAPs take advantage of

nodes caches to propagate messages which were previously lost.

However, the bigger the covered area the lower is the gain the VAP technique presents. This becomes apparent when we look to the graph of Figure 7. The graph shows, in the same experiments, the messages first received through APs and VAPs. As the number of APs nodes increases in the highway environment, the number of messages first received through VAPs decreases. The behavior is similar for the city environment.
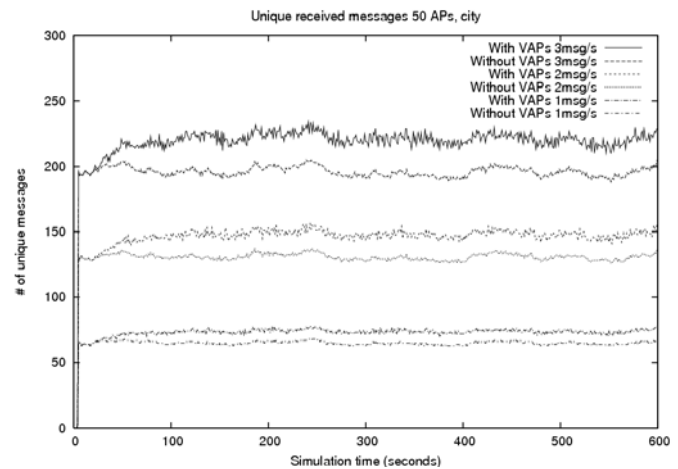
Figure 5 – Unique received messages through the 10 mins of simulation for the city environment
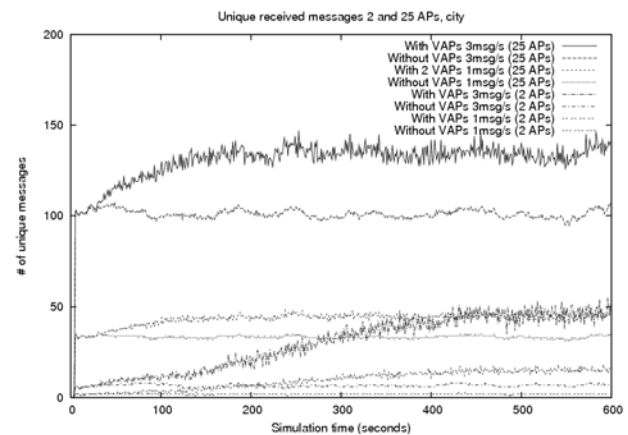
Figure 6 - Unique received messages through the 10 mins of simulation for the highway environment with different number of APs and traffic rates

The use of VAPs accounts for an increase between 61.7% and 134.57% on the total traffic of the network. However, since this increase occurs only in non covered areas, it is not creating interference or delaying the system's APs. Nevertheless, evaluating the number of repeated messages is interesting. On Figure 8, the number of repeated messages for the networks that use VAPs and the ones that do not use it follows the same shape. Increasing the number of messages generated by the VAPs, result in an increasing of repeated messages. As depicted on Figure 8 present the results for different stream rates, and also presents different transmission rates for the VAPs. Each VAP node can either transmit at the same rate the stream is generated or 4 times this rate. For

example, if the stream is generated at the rate of 1 message/second (m/s), the VAP can transmit cache messages either at 1m/s or 4 m/s. The number of repeated messages increases based on the number of VAPs, but as the VAPs assignment is dynamic it decreases when the network coverage increases. This way the number of repeated messages also decreases, as there are less VAPs active. Ten is nearly the best number of APs for this scenario. Given less than 10 nodes, we have lot of uncovered areas and more than that the network get so over provisioned that one AP start to interfere with other and the number of repeated messages increase again, not because the VAPs, but because one mobile nodes start to receive messages from more than one AP.
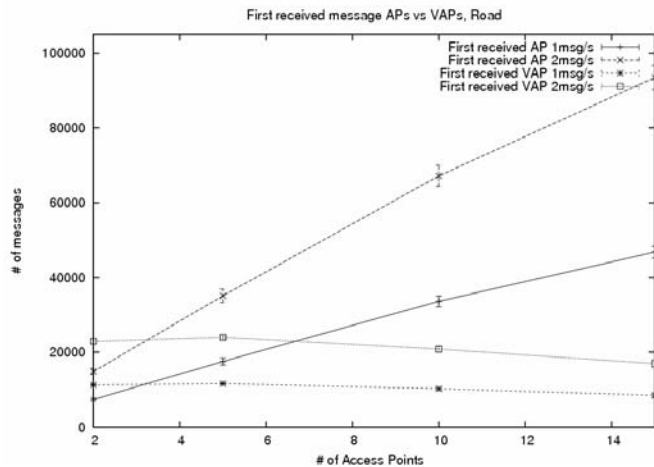

Figure 7 – Number of messages first received from an AP and VAP

Regarding the VAPs spreading messages polices, random, older to newer and newer to older, all three of them presented nearly the same results. However, on average, the random police, i.e. the VAP node sending a random message from the cache, performed slightly better than the others.
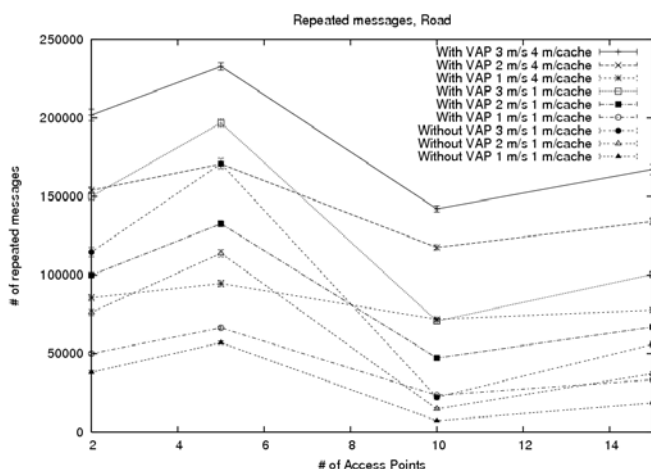

Figure 8 - Repeated messages for the road environment

V. CONCLUSION

This work shows how the use of Virtual Access Points improves the performance of stream traffic for wireless mobile networks. It is a simple yet effective method to increase network coverage and spread stream messages in VANET networks. The technique may increase the packet reception rates by around 30% with effectively no overhead on the APs.

Future steps for this work include determining the optimal number of VAPs in varying environments. Other interesting extension to this work would be evaluating the efficiency of the VAPs to increase the network reliability, i.e. evaluate the efficiency of VAPs in case of APs failures.

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