

Virtual Access Points for Disaster Scenarios

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Abstract— This work focuses on increasing the network coverage for stream traffic in disaster scenarios, which is often critical for preventing damages to property and, most importantly, loss of life. The technique described here, based on the so-called Virtual Access Points (VAPs), and increases the network coverage in a non intrusive and transparent way. It creates a distributed and cooperative cache among the mobile nodes in the affected area. When using the VAP technique, nodes cooperatively work as virtual access points rebroadcasting messages they have in their own cache helping nodes that didn't have access to those pieces of message. The main advantages include that the proposed technique does not rely on any specific characteristic of the network, is transparent, and achieves highly improves the efficiency of stream traffic dissemination resulting in much lower message loss. Our results show that VAPs greatly enhance network coverage. In fact, for some of the scenarios presented, it allows the system to remain operational under conditions it would otherwise be inadequate for stream traffic.

Keywords – Access Points; disaster scenarios; coverage; wireless networks; mobile networks

I. INTRODUCTION

Maintaining communication capabilities in disaster scenarios is a crucial factor for avoiding preventable loss of life and damage to property [8]. Indeed, during a catastrophe such as an earthquake, power outage or flooding, the main wireless network structure can be severely affected. Reports from September 11th point out communications failures contributed directly to the loss of at least 300 firefighters and prevented a good management of the rescue efforts what could have contributed to the loss of many other lives [1][2]. Moreover, communication failures are pointed as one of the obstacles in the co-ordination of the rescue resources in the 1995 Kobe earthquake[3]. These failures further prevented outsiders from receiving timely information about the severity of the damages. These communication breakdowns delayed the relief efforts what could have prevented the loss of numerous human lives.

Furthermore, “historically, major disasters are the most intense generators of telecommunications traffic” [8]. The public communication networks, even when available, may fail not only because of physical damage, but also as result of

traffic overload. Therefore, the regular public networks alone are often not sufficient to allow rescue and relief operations [8].

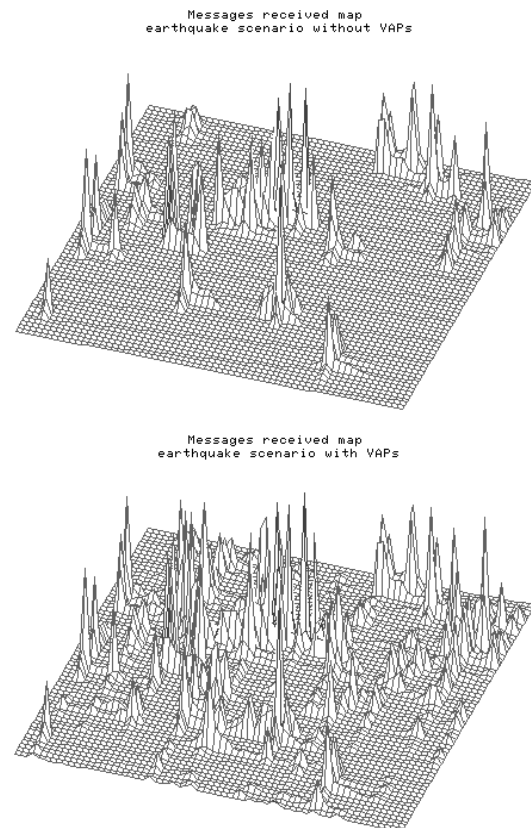


Figure 1 – Map showing the new messages received through the simulated area

When considering catastrophe scenarios, it makes sense to distribute the responsibility of disseminating information among the mobile nodes. This paper presents the Virtual Access concept as an effective method to increase the network coverage within disaster scenarios. More precisely, the main focus of our work is the dissemination of stream traffic that

could be used, in disaster scenarios, to coordinate rescue teams and deliver general information to nodes. We consider scenarios with mobile nodes in a city environment receiving stream traffic through fixed Access Points (APs). This kind of architecture, suited for daily usage, is extremely sensible to disaster scenarios. The virtual access point (VAP) concept [4] intends to, transparently, provide access to nodes in cases where the main network structure is not available. In this way it is a suitable technique to be used in disaster scenarios. This paper addresses three distinct catastrophe scenarios, namely earthquake, flooding and power outage, and the case of APs random failures. The rest of this paper is structured as follows: Section 2 discusses related work. Section 3 further defines the VAPs concept and the target scenarios. Section 4 presents the simulation results and Section 5 concludes this work and presents future research directions.



Figure 2 – Map showing the DC area we use for the simulation, following the orientation of Figure 1 so that it can be overlaid to its graphs.

II. RELATED WORK

Communications infrastructure plays a critical role in all phases of disaster prevention and recovery [8]. However, due to both the nature of disasters, and the fact that communication networks are often not designed to operate under arbitrary load conditions, it is possible they may fail when needed the most [1]. In such situations, often the number and density of users that need to use the network is unusually high. Furthermore, part of the infrastructure can be unusable.

A number of solutions has been proposed that makes use of ad hoc protocols [10][11]. These rely on an ad hoc network or use a hybrid scheme. In the case of hybrid systems, we see the ad hoc used to extend the reach and/or increase the capacity of the fixed network infrastructure. However, no provision is made for cases where the network is fragmented. Furthermore, the transparency of the fixed system is violated and only nodes capable and configured to connect to the ad hoc part of the network can take advantage of its existence.

Disruption and possibly delay tolerant networks can

overcome the problem of sporadic lack of direct communication, however, most are not tuned to work over disaster environments. The Data Mule project [12] and the Message Ferrying scheme [13], 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 [4] in a way that will allow the system to survive a catastrophe. 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 [14] and [15], the nodes are required to follow specific paths and even move in order to help message delivering. The work presented in [15] proposes a multicast protocol for the highway environment where information dissemination through message flooding for VANET environments is proposed. Our proposal advocates using of a more systematic bandwidth efficient approach for data dissemination.

MaxProp [19] is a disruption-tolerant network base on prioritizing both the schedule of packets transmitted to other peers and the schedule of packets to be dropped. It makes use of several complementary mechanisms, including acknowledgments, a head-start for new packets, and lists of previous intermediaries. It is not transparent and is tuned to serve the needs of a vehicular delay tolerant network for connections between its users.

Chen et al. [16] 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 [17]. 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.

Our simulation experiments focus on Vehicular environments in a city. The network architecture we followed is based in the basic multiple Infostation model [18] However, we will refer to the Infostations as Access Points (APs). 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. However, in most cases,

the vehicular networks considered are not tuned to help in general disasters like an earthquake or flooding, where part of the roadside equipment may be damaged and furthermore, the needs for communication are different than that of accident prevention. In our scenarios the traffic can be originating from a source possibly located outside the network that needs to disseminate information. We could use overhead bandwidth of a VANET for delivering streaming data, often requested by more than one user.

III. VAPS FOR DISASTER SCENARIOS

A. Virtual Access Points

The main idea behind the Virtual Access Point (VAP) concept [4] is to have mobile nodes acting as Access Points disseminating previously received messages extending the network coverage to uncovered areas. When a mobile node receives a message it stores this message in a cache. When the node perceives to be in a region without network coverage it rebroadcasts this message as if it was a regular AP. For all practical purposes, from the neighbor nodes point of view, there is no distinction between the messages received from either an AP or a VAP. The main kinds of traffic this technique targets are the ones with no strict time requirements, for example, stream traffic that can be buffered. The Algorithm 1 presents, in high level, the behavior of the VAP algorithm.

This technique is a best effort one; there are no guarantees that all packets of a stream will reach all nodes in the network, however, utilizing the presented technique enables more messages to reach more nodes. In the case of a disaster scenario, this kind of cooperative behavior can be the only way to disseminate useful general information through the network. Thus the mobile stations work as a large distributed and cooperative cache.

B. Evaluated Disaster Scenarios

For evaluation purposes, two possible scenarios are considered. The first refers to a case where the network is damaged by natural causes while in the second case, is when the network is damaged by enemy sabotage. In this paper, the user mobility pattern is used to simulate the movement after the catastrophic events. While this is not necessarily the expected user behavior, it helps us produce results that can be used to understand how the capacity is affected. Note that although considering generating user mobility patterns that would reflect the movement of rescue workers and other users during a catastrophe would be highly desirable, it is very difficult to evaluate any such patterns. In fact any evaluation would require comparison against real traces that seem to be unavailable. The natural disasters evaluated here are earthquake and flooding, the sabotage scenarios are power outage and network random failures, these disaster scenarios where abstracted in the simulation as follows:

- *Earthquake*: The network starts with all the APs and mobile nodes running perfectly. However, at some point, 80% of the existing APs are randomly damaged and excluded from the network. This abstraction permits us to evaluate the effect of the technique when

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If (receive a msg. from an AP/VAP) then
  - Stores the msg. in the cache;
  If (the cache is full) then
    - Throw away the oldest msg;
    - Stores the new message
  end if;
end if;

If (has msg. in the cache && it is in a position where
could become a VAP && was not a VAP in the last
round && did not receive any msg. form other VAP
this round) then
  - Randomly chooses either to became a VAP or not;
  If (became a VAP) then
    - Chases, from the cache, the message(s)
    to rebroadcast;
    - Rebroadcast the chosen message(s);
  end if
end if

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Algorithm 1 –The VAP algorithm, run on mobile nodes that can act as VAP

a major part of the APs disappear randomly from the network without any warning.

- *Flooding*: The evaluated scenario is a flash flooding [5] one. This kind of flooding, is common in mountain regions in spring, heavy rainfall during the a tropical rainy season and in the case of and in the case of dam failures. This situation is abstracted in the simulations by the random disabling of a slice of 20%, horizontal or vertical, of the middle of the network. All the APs in this segment of the network are disabled. This intends to simulate a river crossing the city that flooded in a sudden way.
- *Power outage*: In this scenario, we divided the evaluated scenario in four quadrants. During the simulation one of the four quadrants is randomly chased and all APs on that quadrant are disabled. Complete blackouts are rare in developed countries, but power outages in cities are relatively common if some problem occurs in a specific power station, power line or other part of the distribution system. Commonly the effect of these failures is that part of the power grid goes down letting part of the served region without energy. Such problems could occur by accident, or in consequence of sabotage.
- *Random network failure*: In this scenario random network APs fail and disappear from the network during the regular network operation. The degradation of the network coverage, in this case, is gradual, in contrast to what occurs in the other scenarios. This kind of generalized and chronic failure scenario could be triggered by hacker actions or physical sabotage of the nodes to deny access to the network.

IV. SIMULATIONS

We simulate the movement of vehicles on a 2km² area of

Washington DC city center with cars distributed through it. For each scenario we have 40 different configurations of 30 simulation minutes, with 200 vehicles and a transmission range of 120m. For the city environment the nodes minimum speed is 18Km/h and the maximum is the maximum allowed on that specific road based on the data provided by the Topologically Integrated Geographic Encoding and Referencing system of U.S. Census Bureau. The scenarios follow a realistic mobility pattern generated with the VanetMobiSim [7] tool. Each generated scenario has a number of APs placed randomly. The nodes are initially spread uniformly over the roads of the observed area and then follow the VanetMobiSim realistic mobility model. All experiments keep the same basic configuration but the number of and locations APs is random. Per average we allocate 40 APs but the number varies up to 100.

The simulations were programmed on top of Sinalgo simulator [6], developed by the Distributed Computing Group at ETH Zurich. All the experiments were conducted using Linux Fedora Core release 6 in a Intel Xeon 1.86GHz machine with 16GB of RAM. The graphs are presented with a confidence interval of 99% and each point is the result of the mean of 34 runs with different network configurations for a period of 30 simulation minutes.

The source of the stream generates CBR traffic of 1 message per second and distributed simultaneously by all the available APs. We vary the number of APs, size of the cache, disaster scenario and time, during the simulation, when the disaster occurred.

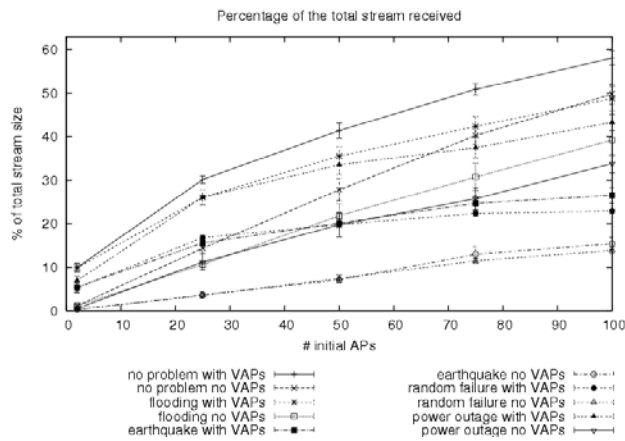


Figure 3—Average percentage of messages received in the network as a function of the initial number of APs for the evaluated disaster scenarios

Figure 1 presents a map where we plotted the received new messages in the considered area with and without the use of VAPs. Through these plots we can perceive that the use of the VAP technique not only increases the amount of received messages, but also spreads the receiving messages points through the observed area. If we compare the plotted map with the actual area map, presented in Figure 2, we can even devise the roads and main intersections from it.

Figure 3 shows the influence of the initial number of APs in

the network and the percentage of messages received. The values represented in this graph refer to the disaster occurring in the beginning of the simulation. We can observe that for all cases the VAP technique provides an increase in the number of stream messages received. The percentage of the stream traffic received is affected by the initial number of APs in the network, with larger number of APs, causing more extensive spread of information in the network. This makes the VAPs efficient for local traffic dissemination. In the best case, when no failure occurred in the network and all nodes work perfectly, using VAP technique provides an increase in the number of received messages that ranges from more than 700%, when the number of APs is two, to 16.6% when the initial number of access point is 100. Note that this ratio is caused by the fact that VAPs allow us to maintain communications in cases where otherwise the system would collapse.

One hundred access points represent, on average, a coverage of 58% of the total simulated area. As expected, the our gain diminishes, as the space covered by access points inverses. This occurs because the VAPs are well behaved and, as it is an opportunistic protocol, the nodes act as VAP only when they are outside the range of any AP and any other VAP. With the increase of the network coverage by the real APs, the regions where a node could act as a VAP decrease and, therefore, the number of messages received through the VAPs decrease. For the disaster scenarios we can detect the same general behavior. Consequently, the percentage of the received stream is larger when the initial number of nodes increases. However, the proportional gain introduced by the VAPs decreases. For the earthquake scenario the gain varies from 1615% to 71%. In this scenario 80% of the network is damaged in the beginning of the simulation, what explains the enormous gain. In this scenario, the number of actual APs is really small and almost all the delivered messages are done through VAPs. We call gain the percent of traffic delivered with help of VAPs over the amount initially delivered without the use of the technique. For example, if we double the number of delivered messages we say the gain attributed to the VAP technique is 100%. For the flooding scenario the gain vary from 753% to

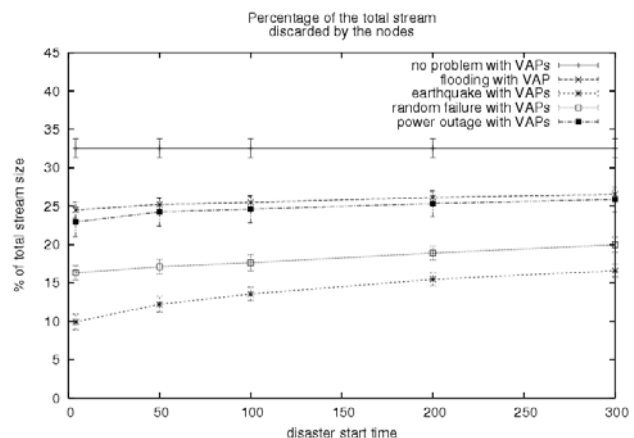


Figure 4 – Number of duplicated messages received as a function of the initial time of each disaster

24%. In the power outage scenario case, the gain varies

between 1122% and 28%. As we can see, the gain is consistent to the fraction of the initial network affected by the disaster, in the flooding scenario 20% of the network is damaged and for the power outage one fourth of the network is affected. The larger the damage in the network, the more relevant becomes the traffic received through VAPs.

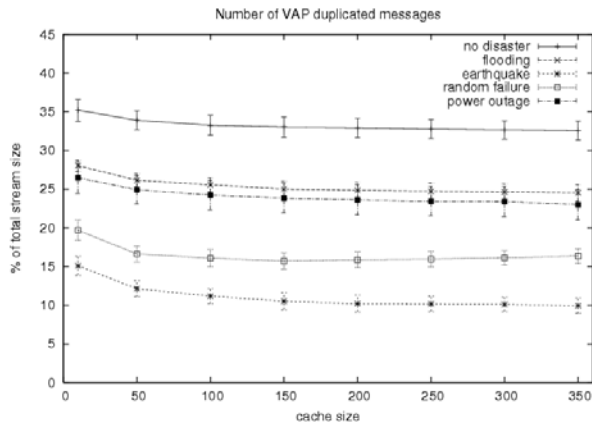


Figure 5 – Number of duplicated messages as a function of the size of the cache with 100 nodes and the disasters occurring in the beginning of the simulation

For the random network failure scenario, the intervals between failures are random, distributed uniformly throughout the simulation time. By the end of the simulation only a few nodes remain functional. The damage for this scenario is not huge at first, as it happens in the earthquake scenario. However the damage is constant through time. In this way, by the end of

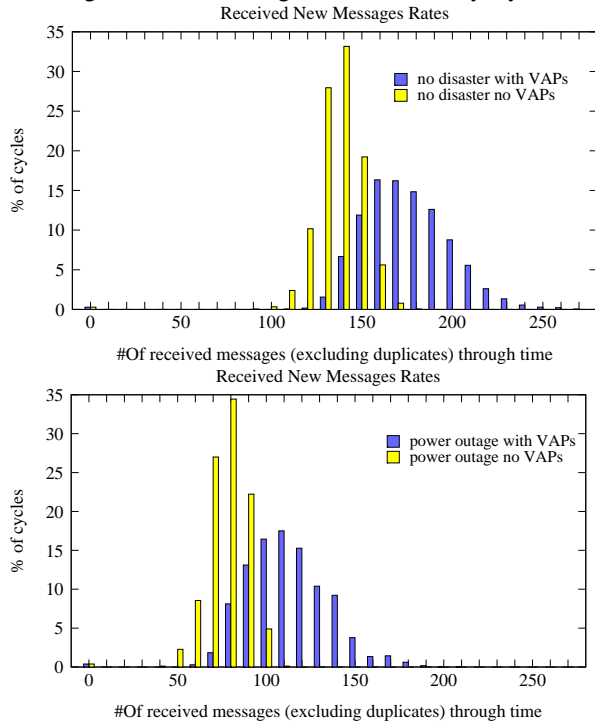


Figure 6 – Transmission rate and variability

the simulation, the damage caused to the network is comparable to the earthquake scenario. Figure 7 shows the

behavior of the random failure and earth quake as a function of time. For the random failure, the gain varies from approximately 1600% to 65%, close to the values estimated in the earthquake set-up. We additionally vary the buffer size and the time the disaster occurred in the simulation. The results are basically equivalent; the only difference is a small increase in the total number of received messages, when we delay the disaster start time.

The graph in Figure 4 shows the number of duplicated messages received by the nodes during the experiments as result of the application of the VAP technique in function of the disaster start time. Figure 5 shows the number of duplicated messages in function of the size of the cache. The values for both graphics are relatively stable. This means that the duplicate messages have a low correlation with respect to the size of the cache and the time the disasters started. As we can see in the graph in Figure 4 the biggest VAP overhead is around 32% of the total number of messages sent in the stream. However, on average 10% of the duplication result from nodes receiving duplicated messages from APs. So the real overhead caused, in the worst case, for the VAPs is about 22% of the network stream traffic generated. When there is no disaster, all 100 APs are working without any problem and a larger part of the stream is received by the mobile nodes from the antennas. However, for the disaster scenarios, where the APs are not fully injecting traffic in the network, the overhead varies between 9% and 16% for the flooding scenario, 16% and 19% for the random failure scenario, 24% to 26% for the flooding scenario and between 22% and 25% for the power outage scenario.

In Figure 6 we can observe that the number of messages received per cycle increases when we use VAPs. Using VAPs, the variability on that range increases. This should be expected since VAPs is a best effort mechanism, and not as effective as APs would have been had they been available.

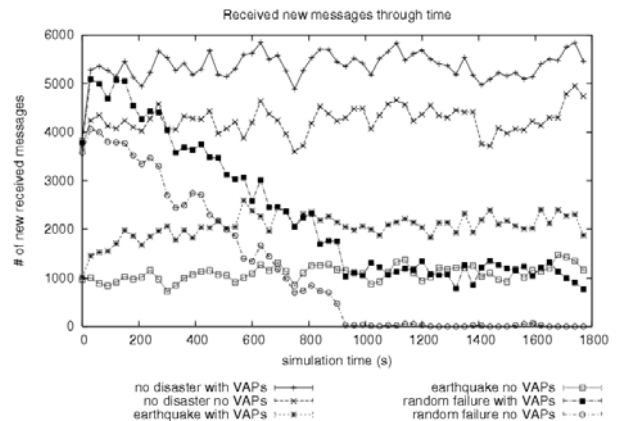


Figure 7 – Received unique messages through time comparing the no disaster, earthquake and random failure scenarios

Figure 7 shows the number of unique messages received through time. We can recognize that the use of VAPs increases the number of unique messages consistently through the time. In this graph it is interesting to notice the behavior of the random failure scenario compared to the no disaster and

earthquake ones. In the beginning of the simulation the random failure and the no failure results closely resemble one another. However, as time passes, the network degrades consistently in the case of the random failure scenario. VAPs decrease the impact of the APs failures, and enables mobile nodes to receive new messages even when virtually no mobile node receives message directly from the APs. During the simulations it is guaranteed that, for any scenario, at least one AP exists and broadcasts new messages. If no VAP existed, only nodes in range of this AP would receive these new messages. Using the VAP technique these few nodes may spread the new message through the network.

V. CONCLUSION AND FUTURE WORK

This paper exploits the Virtual Access Point technique to increase network coverage for stream based traffic in disaster scenarios. As discussed in the simulation results, we observe that the number of received messages for all the evaluated scenarios is increased, often impressively, which is justified since our system manages to remain operational after the initial system has collapsed. The experiments show that the gain in the number of received messages may vary from approximately 1600% to 24% depending on the disaster scenario evaluated. Moreover, VAP is a valuable technique to disseminate network traffic even when no disaster has occurred and can operate transparently to the system. The gain resulting from the application of the VAP technique in the regular network scenario varies from 755% to 16%, depending on the number of APs disseminating data in the network. Since VAPs are only used on uncovered areas, the gain observed is negatively correlated to the AP coverage of an area. As a result of applying the VAP technique, the number of duplicated and irrelevant messages received by the nodes is increased. However, this traffic occurs in uncovered areas where it causes very low if at all interference, and in the worst case, average traffic overhead is increased by approximately 27% in the experiments discussed. When, as in our case, the nodes are mounted to vehicles, energy efficiency is not critical. However, it would be interesting to consider as an extension to this work how to increase energy efficiency when the nodes are carried by humans.

In our future work, we plan to implement the VAP technique on a testbed to evaluate the impact of the VAP in a real environment. In all presented results, the traffic was push based. When considering pull-based traffic, it is much more difficult to offer the level of transparency of VAPs, but one of our future goals is to extend the VAP concept to handle pull-based traffic.

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