RETRACTED CHAPTER: Design of a Network with VANET Sporadic Cloud Computing Applied to Traffic Accident Prevention

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Abstract. The study analyzes the bandwidth available in a segment of route in the VANET network, since this value directly affects sporadic cloud computing. For this purpose, the bandwidth was tested on a highly complex urban scenario, where a number of mobile nodes were used with random conditions both in mobility and in resources of transmission. The results of the tests show that the stability of the bandwidth available in each region is proportional to the number of real mobile nodes in the region. However, a considerable bandwidth is also reached with a smaller number of mobile nodes, but there is no stability in the region, thus causing the network to collapse. The VANET network simulation tool was NS-3, since it is currently one of the most commonly used free software that allows configure the simulation parameters in a vehicular environment. The urban simulation scenario is the historic center of the City of Bogotá, Colombia, which was created with SUMO for obtaining the mobility traces.

Keywords: Machine learning · Proactive control · Traffic · Smart cities · Autonomous computing · VANET

1 Introduction

In the last decade there has been a marked increase in the communication, storage and processing capabilities of mobile devices. These new capabilities, together with the development of wireless communications and the Internet, are driving the development of new and innovative applications, leading the user to have information and entertainment at any time and place [1, 2].

Taking advantage of these technological capabilities, Mobile Ad-hoc Networks (MANET) and Vehicular Ad-hoc Networks (VANET) were created, and can be used in areas of difficult access or without infrastructure. The research focuses on the design,

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evaluation and implementation of new protocols, in scenarios where the main challenge is the continuous changes in the network, due to the variability of the position in the nodes. These advances improve access to new communication services on the roads [2, 3].

Consistent with the above, it is possible to look forward to the future, since these types of networks will be very useful in Smart Cities, due to Intelligent Transportation Systems (ITS), which need robust communication environments to offer access in a high range of multimedia services, upload and download of information, access to social networks, etc. [4, 5]. Deploying these services requires storage and computing capabilities of the nodes outside the communication devices, therefore, a solution would be mobile cloud computing, due to its ability to provide all services by moving the storage and computing capabilities of the nodes to the cloud [6].

At present, the technological properties of portable devices allow to think about the implementation of sporadic Ad-hoc networks among a certain group of users [7, 8].

In this way, vehicles can be provided with a range of communication and storage services in a large territorial space where the coverage of networks such as GSM, 3G and LTE does not exist or is insufficient [9]. This application goes from the network link with users for the provision of vehicular intercommunication requests to the deployment of smart cities through the sporadic cloud protocols and states [10].

This study focuses on the programming and simulation of state machine for the creation of sporadic clouds, in order to illustrate and demonstrate how the system works with the different states that could occur in a given scenario with cars.

The general objective of this research is program and simulate the concept of sporadic clouds in Ad-hoc vehicle networks through the use of free software. The specific objectives are:

1) Analyze the behavior of the state machine for the creation of sporadic clouds according to the type of requirement.
2) Install and configure the simulation program (NS3), which allows its execution.
3) Program and simulate the state machine in NS3 for a given scenario in the city of Bogotá in Colombia.

1.1 Underlying Concepts

This chapter studies the operation of the Cloud-Based Mobile (CBM) state machine, developed in [11].

The project implementation is about the deployment of computer services through a sporadic cloud, applied within a VANET network. This is done to solve the limitations in the processing and storage capacity produced by the mobile nodes within a VANET network. Due to the limitations of mobile nodes when executing a service, it cannot perform its functions normally. For that reason, external resources are needed and the concept of vehicular cloud is used and, in this case, the state machine of the CBM.

The CBM state machine is composed of 5 states (see Fig. 1), for which it allows analyzing the requirements of the real mobile nodes and obtaining these resources within a VANET network. For the routing process it was decided to use the VNIBR protocol, mounted on a virtual layer, improving the performance of the services required by the nodes in mobile environments.

The operation of the CBM is based on several types of events, causing Physical Nodes (PN) to be in some states: Initial, Request for resources, Distribution, Reception and Collaboration [11, 12].

It all starts with the application layer (see Fig. 1), when the node sends a message requesting an increase in resources (M_AugmentationRequest) and activates the CBM process. As a first step, it verifies if this node is in a region of the road segment (note the state in Fig. 2, using Intersection-Flag = 0).

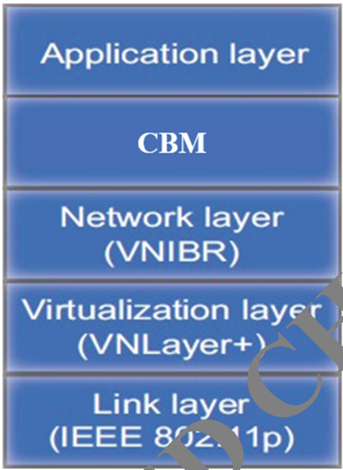

Fig. 1. Chain on communication protocols in mobile nodes [11].

When the L1VN node receives the request, it reviews the possibility of increasing resources with the help of the Collaborator Nodes (CN) that are in the cloud, and due to this, the following scenarios can be presented [13]:

- If there are no CNs in the cloud, L1VN communicates to the requesting node the M_WithoutCollaborators message, and this node returns to the initial state. The application layer receives the M_UnavailableAugmentationService message.
- On the contrary, when there are CNs in the cloud, L1VN informs the amount of resources available through the M_CloudResourceInfo message.
- If resources are sufficient, the distribution of tasks continues. This process takes into account the distribution of the VNs along the segment of the road that is the cloud and the amount of resources available.

Then, the following scenarios [14] can be presented [14]:

- In the first scenario, the requesting node enters a junction before finishing the assignment of tasks.
- If the T_TaskDistribution timer ends its route three times before the task assignment is completed, the node returns to the request state and sends the M_ResourceRequest message back to the nearest L1VN, this is due to the availability of resources change because the CNs are moving.

- However, if the distribution was made before the time is up and the node is in the region, the latter sends the task to the sporadic cloud VN through the M_SendTaskToVN message. The VN presents these tasks to its collaborators through the M_SendTaskToCN message. Finally, the node changes to the task reception mode, only if the VN confirms if it accepts to carry out the assigned tasks [15].

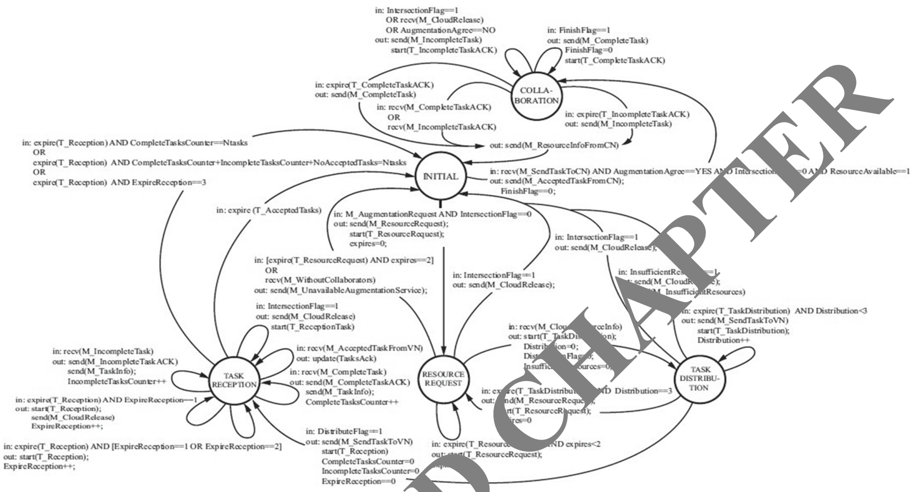

Fig. 2. Approximation of the CBM state machine [11].

The resource requesting node is notified if the CN's have completed the task, if it is incomplete, or did not agree to do it. Then, it sends that information to the application layer through the M_TaskInfo message. If more resources are needed to complete the unfinished and rejected tasks, the steps already mentioned throughout this section are performed. Finally, the requesting node changes to the initial state upon receiving notification of all tasks.

However, if this message is not received the following actions [16, 17] are performed:

- First, the requesting node transmits the M_CloudRelease message to the cloud, with the objective that the collaborators immediately present the progress of the tasks assigned to the collaborators.
- Next, the node waits for incomplete tasks for a period of the T_Reception timer.

With respect to the collaborating nodes that participate in the augmentation task, they move from the initial state to the collaborative state upon receiving the M_SendTaskToCN message sent by the leader of the region and the process is constituted as follows [18–20]:

- If the collaborator completes the requested task, it sends the results directly to the petitioner node because it knows its MAC address, and thus avoids overloading the leader of the region.
- When the collaborator has an incomplete task, as explained above, it must present the progress upon receiving the M_CloudRelease message. To make this request, the CN sends the M_IncompleteTask message to the requesting node. This message contains very relevant information. The CN waits until the confirmation message is received, which are M_CompleteTaskACK or M_IncompleteTaskACK depending on the case.
- The CNs, having delivered the pending tasks, release the resources and the M_ResourceInfoFromCN message is transmitted to indicate the new availability of resources. L1VNs are also informed thanks to the transmission of the M_ResourceDiscovery message, which is sent periodically.
- Finally, the CN returns to its initial state, hoping to return to provide its services when requested.

In this case, only the first 2 states will be analyzed due to the length of the topic, and as a basis for future implementations.

2 Method

2.1 Considerations for Simulation

VANET networks are characterized by the high mobility of their nodes and their changing topology. These features produce failures in communications and communication devices within the network. These deficiencies are mostly due to the processing and storage capacities of the devices that make up that network, since they are less than the required capacities. For this reason, sporadic cloud computing was used as a solution, since it is made up of the CBM in conjunction with the VNIBR routing protocol, which improves the communication and mobility capabilities of VANET networks [21, 22].

In this case, only the following states will be evaluated: Initial and Requirement in sporadic cloud computing, because these states are critical for the process of communication and allocation of resources between nodes, since the VANET network manages and organizes its components (virtual nodes), in order to meet the requirements requested by the mobile nodes (users) of VANET networks.

In order to verify the aforementioned, the experimentation will be carried out on a topology similar to the historic center of Bogota. This was designed with 7 rows and 7 columns (7 × 7 streets), within which are 400 fixed virtual nodes (regions) evenly distributed. The distribution was carried out as follows:

3 fixed virtual nodes are in the track segments, while 1 fixed virtual node is located at each intersection, as shown in Fig. 3.

In addition to these fixed virtual nodes (regions), mobile nodes will be placed within the fixed virtual nodes, so that they emulate the physical users of the network, generating communications and resource requests from one region to another. SUMO 0.23 software was used to generate traffic in the chosen scenario. The generated files containing the movement patterns of the cars were linked to NS-3 (version 3.25) by using NS2 Mobility Helper. In the simulation it is assumed that, initially, all the nodes are already within the scenario and each node performs its route generated in SUMO [23].

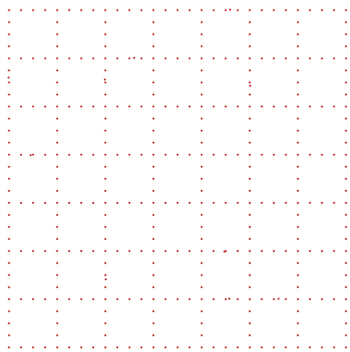

Fig. 3. Simulation scenario: historic center of Bogota.

2.2 Selection of Regions and Intersections for Simulation

Once the stage parameters are defined, the selection of a specific street where there are regions and intersections for the simulation will continue. To do this, first, a track segment and two joint intersections are chosen within the scenario. The regions of the chosen road segment are: 597–598–599, while the regions of the joint intersections are: 596–600, and are physically represented by virtual nodes with identification (ID: 292–296).

After this, a number of mobile nodes are assigned to these regions, and they will randomly request information or processing requirements. With all this, the available bandwidth capacity in each region can be evaluated when a requirement is made. For the simulation, the data rate was configured with 3G–4G technology for the different mobile physical nodes.

The simulation will be carried out 3 times, increasing the number of mobile nodes (10.50 and 100) within a track segment, with the purpose of contrasting the 3 measurements of bandwidth, and thus determining if a higher density of mobile nodes improves resources within the network.

2.3 Simulation of the CBM State Machine

The VNIBR protocol assigns the corresponding level to each virtual node of the topology: the level 1 VNs, which are located at the intersections of the roads; the level 2 VNs, which appear next to the level 1 nodes (they are next to the intersections); and finally, the virtual nodes of level 3, which are among the nodes of level 2. As can be seen in Fig. 4, 5 nodes are assigned for each Way Number (WN), with their respective level. A particularity is that level 1 nodes are repeated for each WN because these nodes are shared for the road sections that are around it [24].

Before starting the program display, a scan of the mobile and virtual nodes of the simulation area is performed. As shown in Fig. 5, the virtual fixed nodes are 400 while the actual mobile nodes can be adjusted in the parameters of the simulation. In this case, 3 tests were performed, the first one with 10 mobile nodes (Fig. 5), the second test was performed with 50 mobile nodes (Fig. 6) and finally, it was performed with 100 mobile nodes (Fig. 7).

The following chapter presents the results obtained from the simulations with the aforementioned considerations, and an analysis of the obtained data is carried out.

```
WN: 38  Region: 592     RegionLevel: 1  Neig.Prev: -1   Neig.Next: 593
WN: 38  Region: 593     RegionLevel: 2  Neig.Prev: 592  Neig.Next: 594
WN: 38  Region: 594     RegionLevel: 3  Neig.Prev: 593  Neig.Next: 595
WN: 38  Region: 595     RegionLevel: 2  Neig.Prev: 594  Neig.Next: 596
WN: 38  Region: 596     RegionLevel: 1  Neig.Prev: 595  Neig.Next: -1
WN: 39  Region: 596     RegionLevel: 1  Neig.Prev: -1   Neig.Next: 597
WN: 39  Region: 597     RegionLevel: 2  Neig.Prev: 596  Neig.Next: 598
WN: 39  Region: 598     RegionLevel: 3  Neig.Prev: 597  Neig.Next: 599
WN: 39  Region: 599     RegionLevel: 2  Neig.Prev: 598  Neig.Next: 600
WN: 39  Region: 600     RegionLevel: 1  Neig.Prev: 599  Neig.Next: -1
WN: 40  Region: 600     RegionLevel: 1  Neig.Prev: -1   Neig.Next: 601
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Fig. 4. Assignment of levels to virtual nodes.

```
scanning topology: 410 nodes...
scan topology... 99 nodes visited (24.1%)
scan topology... 199 nodes visited (48.5%)
scan topology... 299 nodes visited (72.9%)
scan topology... 399 nodes visited (97.3%)
scanning topology: calling graphviz layout
scanning topology: all done.
```

Fig. 5. Scanning of virtual and mobile nodes (10 assigned mobile nodes).

```
scanning topology: 450 nodes...
scan topology... 99 nodes visited (22.0%)
scan topology... 199 nodes visited (44.2%)
scan topology... 299 nodes visited (66.4%)
scan topology... 399 nodes visited (88.7%)
scanning topology: calling graphviz layout
scanning topology: all done.
```

Fig. 6. Scanning of virtual and mobile nodes (50 mobile nodes assigned).

```
scanning topology: 500 nodes...
scan topology... 99 nodes visited (19.8%)
scan topology... 199 nodes visited (39.8%)
scan topology... 299 nodes visited (59.8%)
scan topology... 399 nodes visited (79.8%)
scan topology... 499 nodes visited (99.8%)
scanning topology: calling graphviz layout
scanning topology: all done.
```

Fig. 7. Scanning of virtual and mobile nodes (100 mobile nodes assigned).

3 Analysis and Results

This section will detail the results obtained from the bandwidth capabilities for sporadic cloud computing within a VANET scenario. All these values were extracted from the simulation.

The main objective of the simulation is to determine the capacity of the bandwidth during some requirement of a mobile node within a region. To obtain these values, certain conditions were established in the virtual nodes such as user density, random bandwidth, and the network in which users operate (3G–4G). All this to check the operation of sporadic cloud computing within a VANET scenario and determine if the established proposal is viable.

To obtain realistic results of simulated bandwidths, simulator conditions were maintained for all experiments.

3.1 Bandwidth Assessment (BW) in Each Region of a Road and Intersection

In VANET networks, the speed in the transmission of information (data, images, videos, apps, etc.) is of great importance, since certain values must meet minimum requirements to establish vehicular communications.

Depending on the range of these values, it is possible to determine whether the proposal for sporadic cloud computing for the transmission and processing of information in VANET networks is viable. For this research, the fundamental value used to determine the viability of this implementation is bandwidth.

3.2 Bandwidth

Bandwidth is the amount of information that can be transmitted in a second by means of communication. It depends on the bit handling capacity, the speed of information handling by electronic circuits [25].

the parameters were established in the previous chapter, the graphs of the available bandwidth in a track segment were obtained. Different values were obtained for each metric depending on the transmission rate, range and density of mobile nodes in each virtual node [26, 27].

Figures 8, 9 and 10 show that the implementation of the CBM state machine and the VNIBR routing protocol in a track segment of a VANET network is efficient, because the bandwidth available as a collaboration resource is constant throughout the road segment, but only when there is a large number of real mobile physical nodes within the region of operation. This is understandable since having a greater number of users within a region can provide more resources for it. In addition, these resources are equitable and prolonged in each region of the analyzed road segment.

Another case is when there is a small number of real mobile nodes, since the available bandwidth is not constant and is limited to the mobility of the nodes. This occurs due

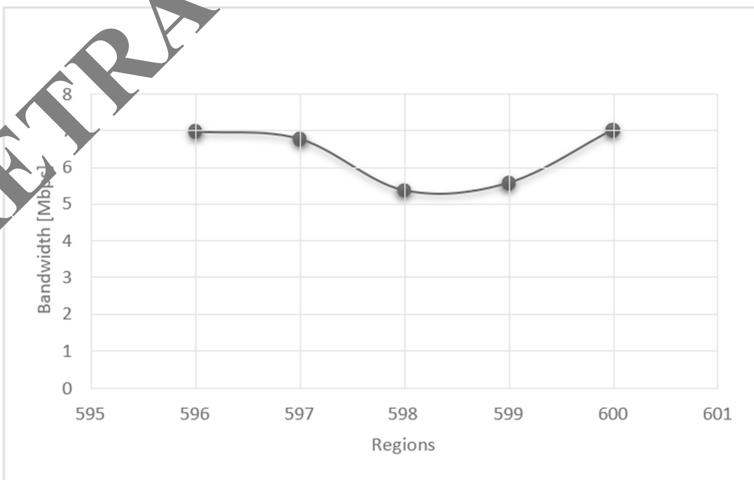

Fig. 8. Available bandwidth by region, simulated with 10 mobile nodes.

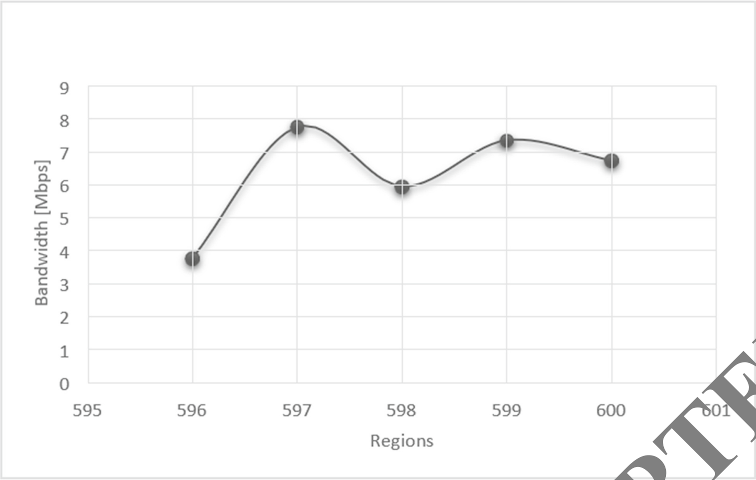

Fig. 9. Available bandwidth per region, simulated with 50 mobile nodes.

to the small number of mobile nodes, since these nodes can change region quickly and the available resources will vary according to the position of the node within the road segment. Although, it would be convenient only in the collaboration of resources since with a small number of users there is less load on the network. Therefore, the implementation shown is efficient in communication tasks in locations similar to the presented topology, but its main deficiency is the stability in the delivery of resources.

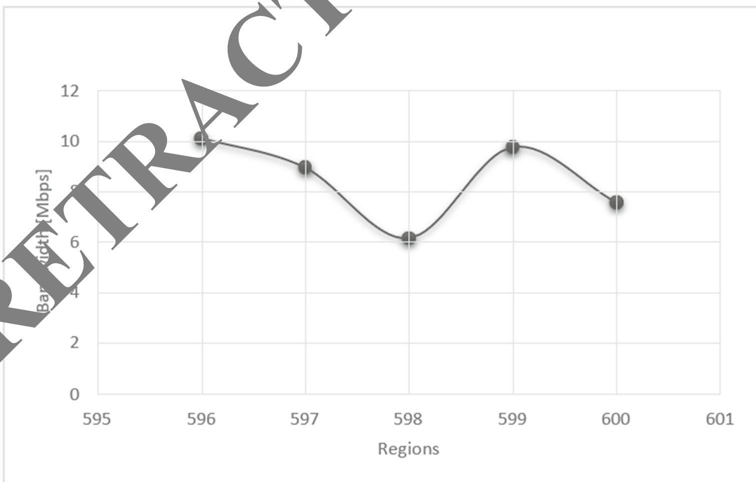

Fig. 10. Available bandwidth by region, simulated with 100 mobile nodes

4 Conclusions

VANET networks are in a position of great expectation, especially due to the scenarios that have several intersections, in which there is lack of coverage, or loss of it due to existing obstacles (buildings, geography, etc.). A fundamental characteristic for the proper functioning of a VANET network is sporadic cloud computing. In this study, the implementation of the sporadic cloud in the VNIBR protocol has begun, simulating a real environment made up of intersections and road segments [28, 29].

In the study, the programming and simulation of a sporadic cloud over VANET networks was projected for a given scenario in the city of Bogotá. This could be achieved through the use of NS-3 and SUMO, which are free software. SUMO was used to obtain the traces that simulate the historic center, which are distributed as grids emulating roads and intersections, and to implement vehicular traffic (mobile nodes) on this. These traces were then used in the NS-3 program to implement the VNIBR protocol and sporadic cloud computing. These programs are widely accepted by Ad-Hoc network researchers due to their high reliability.

VNIBR protocol was used because it is the one that has the greatest adjustment for the proposed scenario, since it is developed to work in environments composed of roads and intersections, and also because it is used in conjunction with the CBM state machine, in which, for its implementation, the first two states (initial and requirement) were used because of their importance, since they serve for the management, location and allocation of resources to users within the network. Between these two states, an analysis was made on the amount of bandwidth available within a region for an urban scenario.

The bandwidth available in the communication is indispensable, since it determines the speed in the transmission of information. In this case, it can be mentioned that the implementation of the 2 states in sporadic cloud computing works optimally due to the stability of the available bandwidth only with a large number of users within a track segment. When there is a low number of mobile nodes, there is the availability of the resource, but this is unstable because it depends on the mobility of the collaborating nodes.

In addition, it can be mentioned that cars work with 3G and LTE (4G) networks which allow better access to the Internet, making it possible for vehicles to handle large bandwidths in scenarios where traffic is slow and bulky. Therefore, the available bandwidth per region is limited by the number of mobile nodes, causing the scalability of the CBM to have restrictions due to the aforementioned characteristic.

Based on the objectives achieved in this study, research lines are generated to continue the development of the entire sporadic cloud, and the implementation could be achieved in a real scenario in future research or projects.

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