Extended iCanCloud simulation framework for VANET-Cloud architectures

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***Abstract*—With the exponential development of cities, the traffic flow prediction has become an important step in the development of transport systems. The main purpose is to improve the logistic services and reduce the cost of the road congestion. In this paper, we propose an extended iCanCloud framework simulation to evaluate the performance of VANET-Cloud architectures. In addition, we propose a VANET-Cloud architecture uses connected traffic detectors (e.g., speed loop trap) to collect traffic data in real time. After that, these data are used to predict the traffic flow. In the simulation step, the proposed architecture was tested by the extended framework, where it provides better performances at peak hours in terms of service latency and data accuracy.**

I. Introduction

The traffic congestion has become a major problem in urban areas, where its negative effects on peak hours can impact the transport and logistics services. The advent of vehicular cloud computing technology promises to alleviate the traffic congestion through providing flexible solutions for the road users. In which, these solutions are accessible via applications rely on internet connectivity. To evaluate such a solution, the experimentation of a real-world scenario in VANET networks will be costly. Where, the simulation shows an essential tool for predicting the performance of vehicular systems. Particularly, the simulation models for vehicular cloud systems warrant our need in this paper where they have not yet been defined. The simulation models in VANET networks are built to predict the final state of the network according to different performance metrics, such as latency, bandwidth and response time. For instance, OMNET++ [9], NS2 [5] and OPNET [4] are most popular network simulator tools for the network performances, such as communication, routing protocols and mobility. Given their popular use among the research community and the evaluation criterion of the simulator, there are several similarities and differences between these network simulators. For instance, these simulators use C++ as a CLI library as well as support the features of the software portability. The NS2 and the Omnet++ are freeware open source, while the Opnet [4] comes with commercial license. Obviously, the Opnet simulator does not allow modifying the source code of the components and the VANET simulation models are very limited. In addition, it is difficult to observe the difference between the simulators with simple simulation models. The distinction can be explored in large simulation scenario, where the complexity increases. Particularly, the complexity increases with the growing number of abstracted components in simulation model. In this way, the network simulators can be differentiated and appreciated. The scalability of the NS simulator is very costly, resulting from the higher utilization rate of the machine resources, the poor mobility model as well [6]. The lack of the simulation mobility models in the physical and MAC layers, prompts researchers to make improvements by developing their own components, such as extending NS2 by Miracle framework [3] to provide an efficient and integrated engine for handling cross-layer. However, the scalability of the Omnett++ [1] has a lower cost, because the network topologies are abstracted to modular simulation via the graphical run time (IDE). This modularity increases the simulation efficiency by abstracting complex networks to single components. Unlike to the NS2 simulator, Omnet++ simulator provides simulation models for physical and MAC layers. For instance, it offers INET [10] as an extensible framework for modeling and simulating the physical and MAC layers of VANET networks. iCanCloud [7] based on INET [10] framework to model and simulate scalable architectures in cloud computing systems. It includes a set of implemented modules for network protocols such as GPRSR/EGPRS [8], ALOHA [2], OSI layers and TCP/IP models. In a simple way, developers can integrate their proposal with other modules of the INET Framework without developing their own modules. In this study, we propose to extend iCanCloud [7] framework to create simulation models for VANET-Cloud architectures. At first, we propose a VANET-Cloud architecture aimed to predict and reduce the traffic congestion during peak hours. To evaluate the performance of this architecture by using the extended framework, we test a predictive traffic model of a real-world scenario in terms of latency and data accuracy. The remaining parts of this paper are organized as follows. Section 2 presents our proposed VANET Cloud architecture for the traffic flow prediction. Section 3 presents the extended iCanCloud simulation by the key components of the proposed architecture. The Section 4 includes the performance of the prediction service. The conclusion of our work is given in Section 5.

II. VANET-CLOUD ARCHITECTURE FOR THE TRAFFIC FLOW

In this section, the proposed VANET-Cloud architecture in figure 1 integrates connected traffic detectors to capture an accurate prediction of short-term traffic flow. It shows the evolution of the classic VANET architectures towards multilayer services model. In particular, the architecture mentions three main layers including, traffic Data collection layer, infrastructure as a service layer and traffic flow prediction layer.

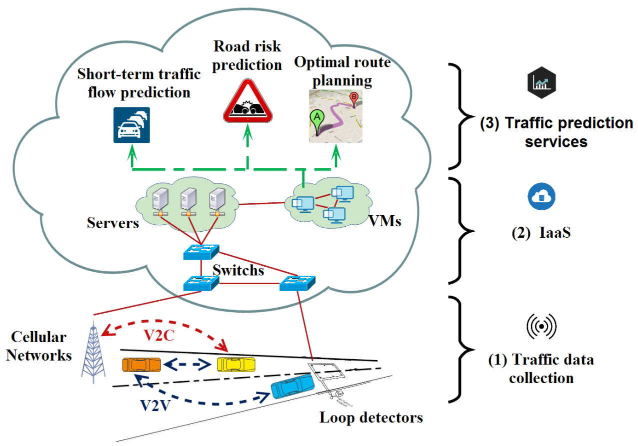


Fig. 1. Proposed VANET-Cloud architecture for the traffic flow prediction.

A. Traffic Data collection

It presents a lowest level of the proposed architecture which includes two sub interfaces, sensing traffic interface and communication interface. In one hand, sensing traffic data interface is destined to pass captured data by the traffic detectors to the cloud infrastructure for an efficient storage and processing. In particular, the proliferation of connected traffic detectors around the specific points in the city will increase the accuracy prediction of the traffic flow. In the other hand, the communication interface use internet connection as backbone to provide an access to the real-time traffic services. The vehicles use the cellular networks (4G, 3G, etc.) as backbone to receive the real/predicted status of the traffic flow. In addition, the predicted data of the traffic flow offer advantages not only for the individual vehicles, but accuracy of these data will optimize also the performance of the other VANET applications such as, calculate the optimal route planning and the estimation of the road risk.

B. Infrastructure as a service (IaaS)

As key components of the proposed architecture, the infrastructure layer comprises a set of physical servers and a set of VMs. Indeed, there are two types of physical servers, the storage servers for storing real-time traffic data and provide online traffic databases, computing servers to provide high computing performances. The virtualized sub-layer is intended to reduce the number of inconsistencies confronted on the performance of legacy VANET networks. For instance, during peak hours, the congestion increases exponentially the number of requests for the road. In which, the vehicles pass to the region server their road claims. The server responses may take a delay time in these periods, because of the overload and available resources almost all occupied. The access to the server resources becomes much easier with the advent of cloud computing, the elasticity of the infrastructure will offer the possibility to adapt to the vehicles demands as quickly as possible.

C. Traffic flow prediction layer

This layer includes the potential cloud services that rely on the accuracy of expected traffic in the short term. The traffic flow prediction for a road section is an expected number of passed vehicles by units of time and space. The prediction process in this layer is mainly based on the raw data collected by traffic detectors (e.g. loop speed trap detectors). In which the expected data are of concern a few minutes in the future. In addition, the process incorporates the near past of the raw data collected in time slot (i.e. period not exceeding a few minutes of time). Using aggregation operators, these data are shifted to predictive parameters for the traffic flow, as demonstrated in our previous work [1]. To predict the traffic flow, we use Choquet integral operator to aggregate raw data to traffic predictors, such as the speed predictor, the density predictor and the arrival time predictor. The fuzzy measurement is the powerful of the operator and it aimed to add the accuracy value to the predicted data.

III. EXTENDED ICANCLOUD SIMULATION

iCanCloud [7] is a simulation framework based on the INET framework for the simulation of scalable cloud computing architectures. One of the main goals is predicts the cost and performance of a given application in the cloud service. In addition, the basic idea of the proposed architecture is to provide the vehicles with an accurate data to adopt an appropriate reaction. To model and simulate the performance of vehicular cloud architectures, we extend iCanCloud [7] simulation platform by the key components of the proposed architecture. As shown in the figure 2. From the conceptual view of the integration, the vehicles are equipped with Ultran interfaces or DSRC (IEEE 802.11 p) interfaces. Through DSRC cards, the vehicles can connect to traditional VANET networks by the V2V and V2I communications. On the other hand, Ultran interfaces allow vehicles to connect via heterogeneous wireless networks such as 3G and 4G networks. In which, the vehicles equipped with dual-interfaces (Ultran and DSRC) serve as internet gateway for vehicles connected by V2V communication. The traffic detectors are installed for each road segment to capture traffic data. It is directly connected to the cloud through I2I communication or by the IEEE 802.11 standard. The road segment is connected by two intersections and it characterized by traffic in real time, such as traffic data, current road density, the average speed and the estimated arrival time. The traffic flow prediction service is a software accessible through SaaS (e.g., accessible by internet) and executed on the virtual machine. In addition, the service is applied to predict the traffic flow from raw traffic data. The hypervisor is software installed in the RSUs, which aims to create for each road segment a convenient virtual system. It intended to carry out captured data to the VM instance. The collaboration between these entities leads to build an effective VANET-Cloud system that predicts an accurate traffic flow. Through timely detection data, the service cloud can disseminates and selects which information can influence the future of the vehicle mobility.

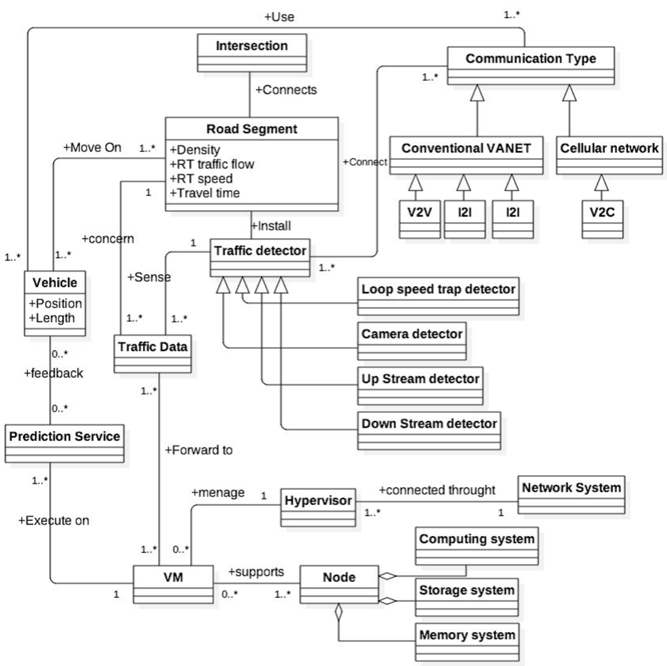


Fig. 2. Conceptual view of the integration.

IV. Evaluation

This section evaluates the performance of an instance of the proposed architecture, the traffic flow prediction in particular. The simulation was performed using the extended iCanCloud framework in Omnet++ [9] simulator. The figure 3 shows the traffic flow model that will be used to evaluate the prediction model of an Algerian highway, where the data are recorded throughout the day using connected loop detectors. In the first simulation step, we estimate the latency of the cloud service to respond to the drivers request. The latency was tested using I2I communication and over heterogeneous wireless network (cellular network). In the second simulation step, we attempt to assess the accuracy of the prediction model through the approximation level between the real status of the traffic and the predicted data by the proposed model.

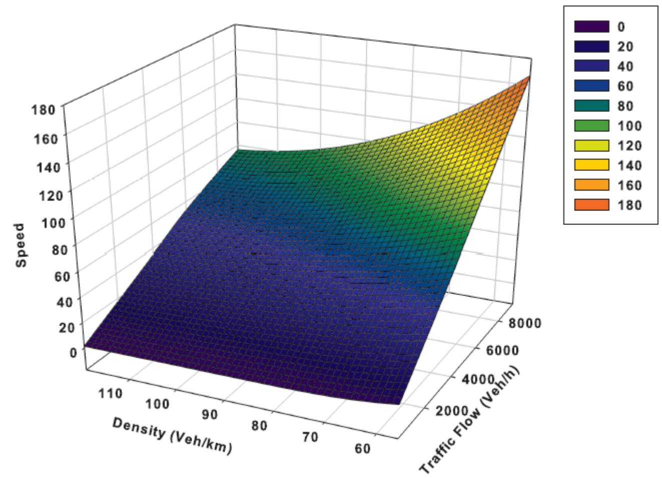


Fig. 3. The traffic flow model.

A. The cloud latency

The cloud service latency is the delay between the drivers request and the prediction service response. The evaluation was performed over two communication models: the IEEE 802.11p and the Vehicle-To-Cloud (V2C) communications. In which, the message size is ranged from 1 KB to 4M. For the transfer of data, the prediction service use small packet size in the case of texture data. However, it can use high packet size when the recorded data are video related. According to the figure 4, the prediction service has a lower latency with vehicle-to-cloud (V2C) communication rather than the latency on IEEE 802.11p.

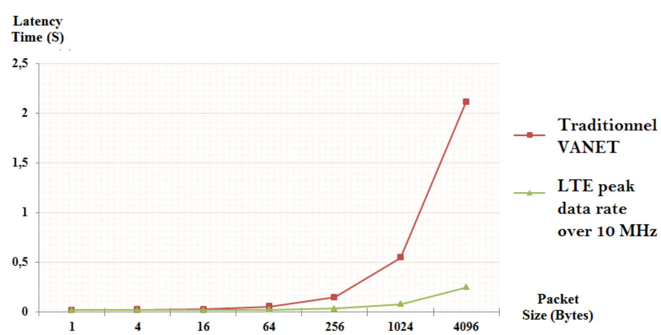
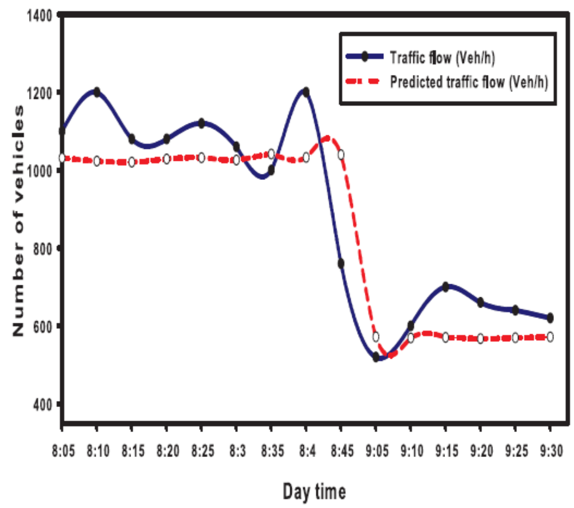


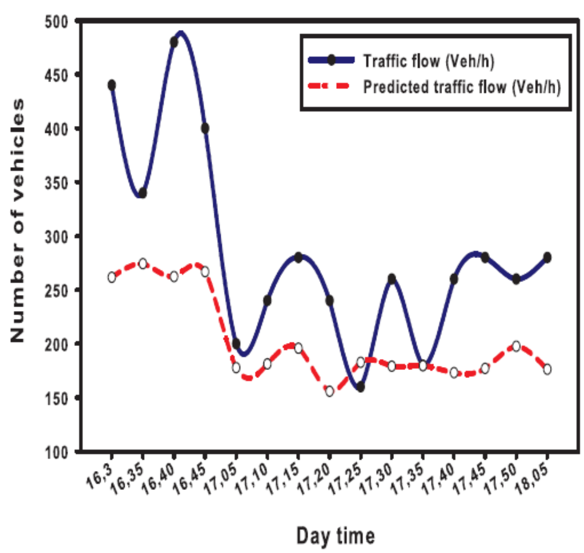
Fig. 4. Conceptual view of the integration.

B. Traffic data accuracy

Based on the described traffic flow model in the figure 3 and our proposed prediction method in [1]. The prediction performance has been tested in two peak hours in the day (case study in highway). The figure 5 shows the performance of the traffic flow prediction at the morning and the evening periods. At the time of the morning, the performance has been tested at 08:05-09:30, while the evening period the performance has been tested at 16:30 - 18:05. We can see that the predicted data are closest to the flow of traffic in real time. In addition, it should be noted that the regression analysis making the short term predictions more accurate through better performance at the peak hours.



(a) Traffic prediction over 1 min time slot



(b) Traffic prediction over 3 min time slot

Fig. 5. Daily prediction traffic flow.

V. Conclusion

In this paper, we presented an extended iCanCloud framework simulation for VANET-Cloud architectures. At first, we propose VANET-Cloud architecture for the traffic flow prediction. The architecture is mainly consists of three layers: the data collection layer, Infrastructure as a service (IaaS) layer and the prediction layer. In the evaluation step, an instance of the proposed architecture was simulated with the extended framework. The proposed architecture provides better performances at peak hours in terms of service latency and data accuracy.

Acknowledgments

This work is subscribed in the context of the thematic research project entitled ”Integrated Road Traffic in Algeria”, our objective is to develop VANETs applications that are ”suspected” of spatiotemporal context, so to generalize the exchange of V2V information’s (Vehicle-to-Vehicle), V2I information’s (Vehicle-to-Infrastructure) and even V2X, and support all communication types (radio, internet, etc.) in their activities.

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