EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA15127
STSM application number: 37657
STSM title: Mobility prediction under network failure conditions
STSM start and end date: 10/07/2017 to 21/07/2017
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Host name: Prof. Susana Sargento and Dr. Lucas Guardalben, Uni Aveiro, Portugal
Working Group: WG4

PURPOSE OF THE STSM:

Mobility prediction is about to forecast the flow of crowds (both vehicles and mobile users). Mobility prediction is of great importance to traffic management and public safety, and is a very challenging task as it is affected by many complex factors. Nowadays, people use Google Maps to get real-time traffic recommendation services to guide their daily travelling. However, what happens if the communication networks are broken, and people have no Internet access to those services. Is it still possible to make predictions of crowd flows by learning from previous dataset? In this STSM, we target to tackle the problem of mobility prediction of vehicles under network failure conditions, which means to predict vehicle future locations only using their past and current context information without any Internet access. We apply our rich experiences in machine learning techniques to find patterns from vehicles' historical movement traces and propose solutions to forecast possible traffic jam in urban city areas under network failure conditions.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

In order to make traffic predictions for vehicle networks under network failure conditions, we need raw data that are collected from real world systems. Veniam [1] is a spin-off of the Institute of Telecommunication at the University of Aveiro. The host of this STSM, Prof. Susana Sargento at University of Aveiro, is also the co-founder of the company, which gives us the opportunity to access the data under a mutual agreement without any privacy concern. Veniam has successfully deployed the largest real-world vehicular networks (VANET) testbeds in the city of Porto, Portugal. This testbed interconnects more than 600 vehicles (public buses, garbage trucks, and municipality vehicles) in order to provide a set of services such as Ineternet access on board and delay-tolerant communications to transport non-urgent information. The testbed collects a huge amount of raw data everyday, including the current connected Road-Side-Unit (RSU) of the vehicle (On-Board-Unit), communication channel status between the connected RSU and OBU, speeds and directions of vehicles, etc. These raw data provide a solid basis for the vehicle mobility prediction tasks.

When network failures happen, no more Internet access is available for smartphone users. Under these coditions, the vehicle mobility prediction can only be made from the current data (such as connected RSU ID, speeds, buffered maps, etc) and the data that were collected in the past. During this STSM, we applied and modified our in-house Dynamic Bayesian Networks-based mobility prediction algorithms [2] to estimate the future connected RSU of the vehicles. Our algorithm models the vehicle future mobility prediction as a first order Markoc chain, in which the future location (next connected RSU) of a vechicle depends on its current connected RSU, current time and the weekday. The effectiveness and performance of our model have been proven in our previous works of predicting future locations of LTE mobile users [2]. Therefore, during the staying at the host institute, the STSM grantee works closedly with the host institute senior researcher Dr. Lucas Guardalben, who has the direct access to the dataset that are collected from the Veniam testbeds. In order to feed the original data into our prediction algorithms, certain data pre-processing tasks are needed. We perform this data pre-processing together and apply the prediction algorithm over the processed data. All the experimental data have been processed to be anonymous.

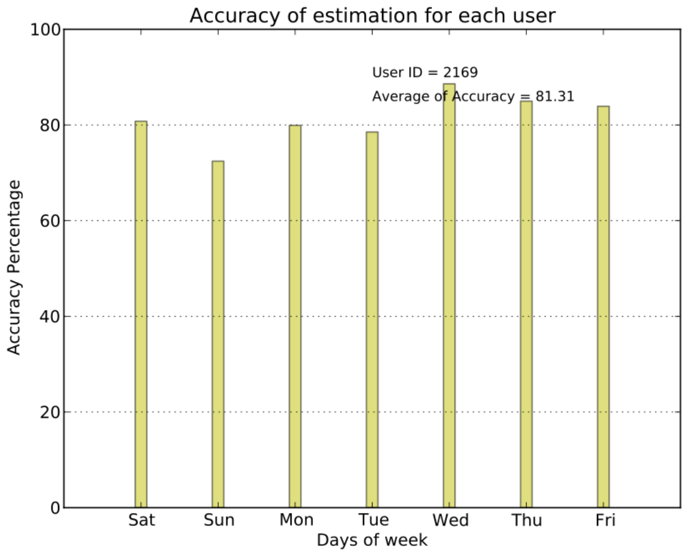
In order to validate the prediction accuracy of our algorithm, we have chosen a partial of the original dataset of 6 months, and divided it into two parts. The first part is used for learning the mobility patterns of vehicles, and making predictions of their future locations (in terms of connected RSU). The second part is used to validate the accuracy of the prediction, by comparing the predicted future locations with the real locations. As a typical prediction task, we use the 70% of the dataset as the training dataset, and use the remaining 30% of the dataset as testing dataset. We have conducted multiple experiments with different OBU IDs (different vehicle ID), and mearure the perfoamnce under different day of the 6 month period.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The main focus of this STSM is to estimate the future locations of vehicles, given their current and past context information. This is like to estimate the future locations of cars in the network failures conditions, where no Internet access is available. Therefore, only the current and past information can be used to make the prediction. We have performed various experiments for different OBU IDs, which means different vehicles. In this experiment, we choose only the public buses, this is because bus routes are rather static, while the taxi routes are more random.

We have proposed a mobility prediction algorithm, which benefits from Dynamic-Bayesian Networks (DBN) [2]. The rationale behind using DBNs is that the next locations (next connected RSU) of a vehicle depends on: its current connected RSU, the current time, and the day of week on which the vehicle is in movement. We model the vehicle future location distribution using both a location dependent distribution and a temporal dependent distribution. Hence, each of them can be modeled as a simple first order Markon Chain (MC), which encodes the probability of transitions between the RSUs. The number of valid states in the derived MC for each user highly depend on the quality of the data trace in each day, so the trace dataset plays a key role in the accurate prediction. In order to evaluate accuracy of our algorithm, for each vehicle OBU ID we selected randomly 50 states out of the MC states derived for each particular day of a week from the original dataset. These selected states represent the random times and IDs of the RSUs that vehicle has been there. Afterwards, we perform the calculation of predictions to find the future possible connected RSUs for those users in the next X minutes (e.g., X=20 means to predict vehicle locations in 20 minutes). We repeat the predictions for the same radom MC states. Then, the Mean Absolute Error (MAE) of the corresponding test points, which are chosen from the learning and testing datasets, is computed to obtain the prediction accuracy for each vehicle ID in a particular day of a week. Details about how do we measure the accuracy can be found in our previous work of [2].

Figure 1 shows the prediction accuracy of OBU ID 2169, which depicts the average prediction accuracy of each single day of a week. For the reason of space limit, here we only present the results of one OBU ID, and more detailed evaluation will be included in the future publications. As we can see, for this specific OBU ID, the average accuracy can reach almost 82%, and for some weekday (Wednesday), the algorithm can generate nearly 89% accurate predictions, which is a very good result.



In addition to the first order MC soliution, we also implemte a novel second order MC solution for predicting vehicle future locations. However, the results are not as good as we expect, which is mostly due to the fact that the vahicles are not connected to any RSU in most of the time. We have proposed another solution to tackle this problem, and we will include all the results in the future publications.

FUTURE COLLABORATIONS (if applicable)

Based on the achieved results that are directly derived from this STSM and the common research interests, the home institute of the STSM grantee and the host institute have agreed to further enhance the collaborations to combine the expertises of two institutes. This enhanced collaborations will enable us to submit joint publications, visit each other more often, and prepare research proposals together.

To benefit from the scientific results of this STSM, we have two publication plans in the coming three months. The first one is about extending an existing work of the host institute, which is about content migration and caching mechanisms in the Catch-up TV services. The current solution is based on a static scenario, in which intelligent caching mechanisms are implemented on static storage. We will extend this work to mobile VANET scenarios, in which content will be cached at RSUs to reduce the content retrival time for users on the vehicles. To do this, we will integrate the vehicle mobility prediction tasks that are performed in this STSM, with Catch-up TV content migration services. We have already set up the emulated client prefetching testbeds, and we will include the results from this STSM and the content retrival time when using/without using the vehicle mobility prediction services. We plan to publish these results by September 2017. The second joint publication plan is about using the vehicle mobility prediction results to estimate the traffic jam in the urban city areas. To do this, we started from one main street in the city of Porto, and analysed the traffic conditions and the correlated data (e.g., vehicle waiting time at the crossroads). However, due to time limits of this visiting, we could not perform any experiment within the period of this STSM. We plan to continue this activity in the future, and we target at a journal submission to publish these results.

In addition to the planned joint scientific publications as direct collaborations, we also find that the two groups have many research topics in common. For instance, both groups are working on establishing autonomous Unmanned Aerial Vehicles networks, and we decided to exchange our expertises and project results to enhance the work on these topics.

In the future, we plan to strength the collaborations by having regular telephone meetings, more frequent visiting of each other (maybe via another STSM exchange in the next session), and preparing EU proposals on topics that are interested for both institutes.

References

[1] Veniam https://veniam.com/
[2] M. Karimzadeh and Z. Zhao and L. Hendriks and R. de O. Schmidt and S. la Fleur and H. van den Berg and A. Pras and T. Braun and M. J. Corici (2015 October). Mobility and bandwidth prediction as a service in virtualized LTE systems. In 2015 IEEE 4th International Conference on Cloud Networking (CloudNet). DOI: https://doi.org/10.1109/CloudNet.2015.7335295
[3] J. Nogueira and D. Gonzalez and L. Guardalben and S. Sargento (2016 June). Over-The-Top Catch-up TV content-aware caching. In 2016 IEEE Symposium on Computers and Communication (ISCC). DOI: https://doi.org/10.1109/ISCC.2016.7543869