Poster Abstract: Feasibility of Floating Content in VANETs

Gaetano Manzo
University of Bern & HES-SO Valais,
Switzerland
gaetano.manzo@hevs.ch

Gianluca Antonio Rizzo
HES-SO Valais,
Switzerland
gianluca.rizzo@hevs.ch

***Abstract*—VANETs can benefit by using an infrastructure-less model such as Floating Content (FC) in absence of infrastructures or as support to these latter. This work presents FC performances in vehicular context by using Random Waypoint mobility model.**

I. Introduction

In VANETs, infrastructure support to vehicular communications, in the form of Road Side Units, is not always available, e.g. infrastructure malfunction [1]. Moreover, the deploy of this latter is a very invasive and expensive solution not always possible. In order to support applications for smart cities, to implement communications for autonomous vehicles coordination and for advanced road safety systems, in absence of infrastructures or as support to those, we need an infrastructure-less communication scheme, Floating Content (FC). FC is an infrastructure-less communication paradigm, which allows probabilistic content storing in geographically constrained location called Anchor Zone (AZ) and over a limited amount of time, by exploiting opportunistic replication between mobile wireless nodes. So far, analytical performance modeling and characterization of FC has been limited to pedestrian scenarios. A model including all the geometric features of the road grids would be hard to parametrize in practice, requesting many parameters, and it would need an ad-hoc treatment (e.g. highway, intersection and so on) which would defeat the purpose of having an analytical model.

This work presents an analytic approach to performance modelling of FC in vehicular scenarios. Our approach is based on mapping of some of the features of vehicular mobility patterns into a random waypoint (RWP) model with pause. This allows a performance modelling of FC which abstracts from many of the details of the vehicular mobility scenario, such as speed distribution, geometry of the road grid, and others. Moreover, random waypoint with pause allows the simulation of several mobility contexts (e.g. traffic light, car crash and so on). Numerical evaluations show that the model performs very well even in settings where the road grids and the mobility patterns show a high diversity.

II. The Floating Content Service

We consider an area where nodes move according to an arbitrary mobility pattern. We assume at some point in time a node (the seeder) generates a content item and it defines a circular AZ (Fig. 1a). Then within the AZ, whenever a node having a content item comes into the transmission range of some other node which does not have it, the content item is replicated opportunistically (Fig. 1b). As the AZ is assumed to be the area within which the content item is of interest to passers by, nodes going out from the AZ erase all the contents stored (Fig. 1c). The ratio between the set of nodes carrying each content item and the total amount of nodes inside the AZ is the floating content *availability*. This value influences the *Success Probability* of the floating content, i.e. the probability for a node to get the content item during its sojourn in the AZ.

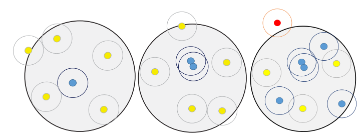

Fig. 1: Floating Content Communication Scheme. a) Seeder defines AZ. b) Opportunistic content replication. c) Content erased for the nodes outside the AZ.

III. State of the Art

The FC concept was first introduced in [2]. This work proposes a model for evaluating the probability for the content to float indefinitely over time. Subsequent works, such as [3] and [4], have focused mainly on FC performance in pedestrian scenarios, and in settings characterized by low node mobility. Indeed, less dynamic setting make the content less likely to disappear from the AZ. [4] considers FC in an office environment, proposing a performance model based on the mapping of the mobility features to a Random Direction mobility model which does not capture adequately the impact of the specific features of office mobility (such as distribution of time spent in movement). [3] adopts a Poisson jump mobility model within campus environment, where nodes communicate with each other via Bluetooth. Such model assumes no content is exchanged when nodes are moving, and hence it does not apply to contexts, such as the vehicular ones, where "on the fly" exchanges are predominant.

IV. A two-steps method for performance modeling of FC in vehicular setting

Our method is based on two steps. The first step, consists of vehicular mobility patterns features extraction in order to parameterize a random waypoint model with pause. In the second step, we apply analytical methods to estimate the success probability in FC service. To reach this goal, we consider an AZ with a given radius and arrivals rate (i.e. the frequency of nodes entering into AZ). Within AZ, nodes move according to random waypoint with pause mobility model. A node moves from a random waypoint to another with a fixed speed. Every time a new waypoint is chosen, with a probability $(1-p)$ it is outside the AZ. In each waypoint, a node stops for a time that follows an exponential distribution. The time required for a node to reach the next waypoint T_{move}, plus the time spent at this waypoint T_{stop}, is called *epoch*. Therefore, the total time that a node spends within AZ is a sequence of epochs. Under ergodic properties, waypoints are an independent stochastic process, moreover, epochs are i.i.d.. This allows us to estimate the number of successful exchanges content by focusing on a single epoch of a single node. Then, generalize for the whole set of nodes and epochs. The success probability P_{succ} is directly related to the probability to get the content in an epoch P_{epoch}. This latter is related to *node contact rate* and *node density*, both depending on the parameters such as average node speed, node transmission range, T_{move}, T_{stop} and node arrivals rate into AZ. P_{epoch} can be evaluated considering two phases. When the node is moving and when it is not. In both situations, by considering Poisson Spatial Process, we evaluate the probability that a node gets the content item (i.e. success probability in that phase). Finally, given P_{epoch} we evaluate the success probability by a binomial distribution (see equation 1).

$$P_{succ} = \frac{P_{epoch}}{1 - p(1 - P_{epoch})} \tag{1}$$

V. NUMERICAL EVALUATION

In order to assess our method and analytical success probability, Omnet++ has been used to place two simulation scenarios. In each simulation we define and/or estimate a set of parameters such as Anchor Zone radius (R), node speed and node transmission range (resp. v and r), T_{stop} and T_{move}, node arrivals rate (λ) and probability for a node to exit the AZ (p). At a later time, we evaluate availability and empirical success probability. Finally, processing an interval of confidence we assess our model.

In numerical assessment first phase, we have simulated RWP model with pause, with the aim of evaluating the impact on the success probability, of effects such as clusters and border effects which have not been modeled. We consider an AZ with a radius $R = 50m$. Fixed the probability for a node to jump out (i.e. the probability of choosing the next waypoint outside AZ) $(1 - p) = 0.1$, we assume that each node moves with a speed of $1m/s$. Node arrivals rate is about one every $0.1s{-}1$. We evaluate success probability and the availability over the ration between node transmission range radius r and AZ radius R, for several moving mean time percentage $q = \frac{T_{move}}{T_{move}+T_{stop}}$. Results show the impact on the success probability of effects, for the chosen range of values r and R, is small enough to guarantee that analytical values are within the confidence interval of the simulation values (in Figure 2).

In a second setup, we perform FC in a real scenario, using Luxembourg mobility traces relative to 24h [5]. The average time moving and pausing for a node, in the consider scenarios, are $T_{move} = 25s$ and $T_{stop} = 15s$ respectively. Mean node speed $v = 18m/s$. We evaluated success probability over the ratio between node transmission range radius r and AZ radius R within Luxembourg City in several locations as shown in Figure 3. The AZs are placed in three areas, residential (R), city center (C) and industrial (I), each about $200000m^2$ (mobility parameters in Table I). From these first evaluations, results from analysis are within 5% of the measured success rate (Table II). Though only preliminary, these results show that our approach is promising and holds the potential to map vehicular mobility features into our model.

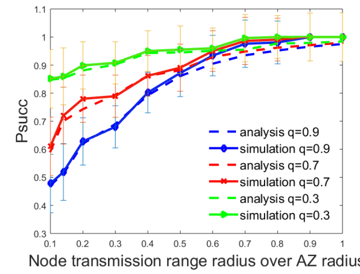

Fig. 2: Success probability over node transmission radius changes.

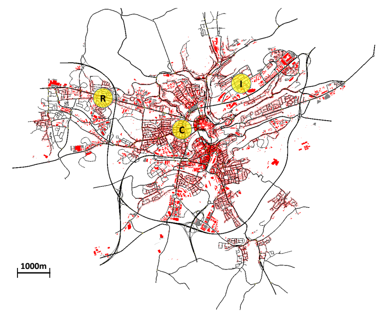

Fig. 3: Map of the area of Luxembourg on which simulations have been run. The three yellow areas correspond to three AZ with $R = 260m$, situated in the city center (C), in the industrial district (I), and in a residential district (R).

TABLE I: Parameters estimated of Luxembourg city setup, for $R = 260m$ of the areas in 3.

District	Mean arrival rate $[s^{-1}]$	Mean sojourn time $[s]$
City center	0.088	360
Industrial	0.094	400
Residential	0.010	180

TABLE II: Luxembourg simulation results. Model vs Simulation.

	Residential		City center		Industrial	
r/R	P_{model}	P_{sim}	P_{model}	P_{sim}	P_{model}	P_{sim}
0.3	0.618	0.640	0.770	0.741	0.891	0.920
0.5	0.674	0.707	0.854	0.894	0.925	0.956
0.7	0.745	0.771	0.8957	0.9241	0.940	0.973

VI. FUTURE WORK

Currently, we are using real mobility scenarios in order to compare the results with our model. We would like to use this approach as support to localization system as GPS. Indeed, a vehicle could estimate its position though the position of another vehicle.

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