

A Simple Approximate Analysis of Floating Content for Context-Aware Applications

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I. INTRODUCTION

Context-awareness is a peculiar characteristic of an ever expanding set of applications that make use of a combination of restricted spatio-temporal locality and mobile communications, to deliver a variety of services to the end user. It is expected that by 2014 more than 1.5 billion people would be using applications based on local search (search restricted on the basis of spatio-temporal locality), and that mobile location based services will drive revenues of more than \$15 billion worldwide [1]. A common feature of such context-aware applications is the fact that their communication requirements significantly differ from ordinary applications. For most of them, the scope of generated content itself is local. This locally relevant content may be of little concern to the rest of the world, therefore moving this content from the user device to store it in a well-accessible centralized location and/or making this information available beyond its scope represents a clear waste of resources (connectivity, storage). Due to these specific requirements, opportunistic communication can play a special role when coupled with context-awareness. The benefit of opportunistic communications is that it naturally incorporates context as spatial proximity is closely associated with connectivity.

Recently an opportunistic communication paradigm, known as *floating content* (FC) [2], conceived to support server-less distributed content sharing was proposed. It aims at ensuring the availability of data within a certain geographic area called *anchor zone* (AZ). Within the AZ, any time a user who is unaware of the content enters the transmission range of another user possessing it, the content is shared opportunistically. Nodes delete content once they go out of AZ. In recent literature ([1], [2]), authors derived an asymptotic condition called *criticality condition* under which content floats asymptotically.

II. THE PROBLEM

In state of the art ([1], [2]), FC is explored from the point of view of feasibility, with a focus on the conditions (*criticality*) under which information asymptotically floats within a region. But from an application perspective, it is not sufficient that the content floats asymptotically: it is possible

that content floats in an area but very few nodes entering in that area come to know about that content. If FC is to be used as a communication paradigm supporting context-aware applications, then then an open issue is how to choose and tune FC design parameters in order to successfully support such applications.

III. OUR APPROACH

We develop a simple but very accurate approximate analytical model that explains the correlation between the main design parameters of FC and the primary performance parameter from an application perspective. The key design parameters of FC are: (1) AZ radius (R_2), that acts as replication range, (2) node transmission range (r), and (3) average node density (λ). Applications that use FC can be grouped into two categories. For each of them, we formulate a specific definition of success probability, which we take as the main performance parameter for that application. This definition depends upon the Range of Interest (ROI) having a radius R_1 with $R_1 \leq R_2$. ROI is application specific and depends upon the contextual properties of content to be floated. For instance, for a parking finding application, information related to a free parking spot may be of interest to cars within 200 meters range, so in this case, ROI is 200 meters. For the first category of applications, it is required to deliver a message to end users before they leave ROI, because the message is expected to trigger some specific actions, like visiting a famous tourist attraction, or a restaurant. For such applications success probability is the probability that a node entering the ROI gets the content before exiting the ROI. For the second category of applications, it is required to deliver the content to users before they enter ROI. For instance: in case of an accident or traffic jam, a user should be notified about the situation before entering a certain geographic area (ROI), so that he/she can make an informed decision about alternate paths. For such applications success probability is the probability that a node gets the content before entering the ROI.

For developing our model, we consider Random Direction Mobility Model (RDMM), which is known for its simplicity and analytical tractability. It is proven that under RDMM, at

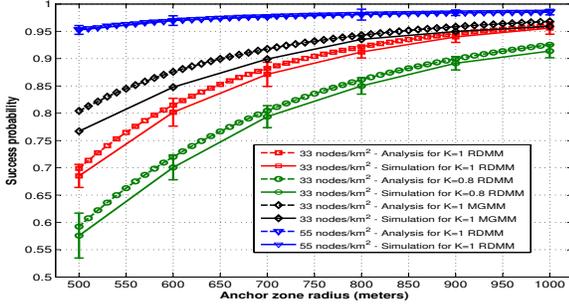


Fig. 1. Success probability vs. AZ radius for $R_1 = R_2$.

any time instant users are distributed in space according to Poisson Point Process. We exploit the geometric properties of RDMM in order to obtain a probability density function of path lengths inside AZ for both categories of applications. We restrict ourselves to the regime where floating probability within AZ approaches to 1 (as considered by [1] and [2]), and derive expressions for distributions of nodes with and without content for a given node density and AZ radius.

$$P_S = \sum_{k=1}^{\infty} \left(\int_{l_{min}}^{l_{max}} \left(f_L(\ell) \frac{(2r\ell\lambda)^k e^{-2r\ell\lambda}}{k!} \right) d\ell \right) \left[1 - \left(1 - \frac{Q\bar{n}}{(\bar{m} + \bar{n})} \right)^k \right] \quad (1)$$

The equation 1 for computing success probability has two main parts. The first part is the probability of meeting k nodes along a path of length ℓ , which depends on the pdf of the path length ($f_L(\ell)$) and the number of nodes encountered along path of length ℓ , which is expressed as a Poisson distribution with an intensity $2r\ell\lambda$ due to properties of RDMM. The second part is the probability that at least one of k nodes met has content. It is based on the assumption that system is in equilibrium state where the average nodes with and without content remains constant (as considered by [1] and [2]).

A key characteristic of our modeling approach is that success probability is computed from few primitive FC system parameters and the probability density function of the length of the path followed by users. This allows the analysis to be generalized to different settings, including different AZ shapes, different user mobility patterns, different user speed distributions, different service and application models. Moreover, our analysis can also be used to tune the system design parameters of FC to get the desired application performance.

IV. SIMULATIONS AND RESULTS

We validate our analysis with extensive simulations using OMNeT++. Simulation results reveal that the predicted success probability is indeed very accurate. In Fig. 1, we observe the impact of AZ radius on success probability. Fig. 1 confirms that our model can be generalized to different settings because it accurately predicts success probability for the generalized Manhattan Grid Mobility Model (MGMM). Figs. 2 and 3 show that increases in either AZ radius (R_2), or node density result in increased success probability for both applications.

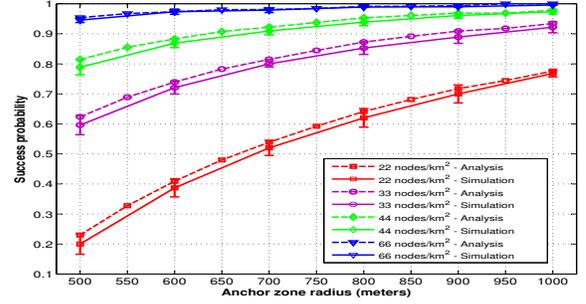


Fig. 2. Success probability for application 1 with ROI = 200m.

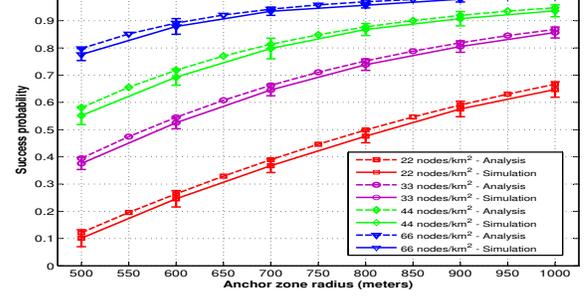


Fig. 3. Success probability for application 2 with ROI = 200m.

Results pronounce that criticality condition (condition under which content floats derived by [1] and [2]) does not give any idea about the performance of an application using FC. For instance, in Fig. 1, for $22 \text{ nodes}/\text{km}^2$, under 500m AZ radius, criticality condition is satisfied, but the success probability is not reasonable (below 60 percent). A 100 percent increase in AZ (900m) is required for achieving a reasonable success probability of 90 percent, and our model can be used to tune the AZ radius for getting the desired success probability.

V. CONCLUSIONS AND FUTURE WORK

We developed a simple, approximate analytical model for computing success probability for applications using floating content as communication service. Despite simplicity, our model computes very accurate success probability values for a wide range of anchor zone radii and node densities for different mobility models like RDMM and MGMM, as proved by comparison against our initial set of simulations.

Our models can be adapted to several different categories of context-aware applications, and the model predictions can be used in order to tune key parameters of the system to achieve the required performance with minimum overhead.

Future work will be aimed at extending our analysis to other mobility models and also incorporate a more realistic communication model including contention, collisions, and retries.

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