A study case of opportunistic multihop communication using mobile platforms for very sparse infrastructures

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***Abstract*— In this paper, a sparse infrastructure relying on the mobility of multihops capable nodes is addressed. The performances in terms of relative delay to deliver a message, maximum memory occupation and number of hops are presented for non delay sensitive services and with simple model of traffic and mobility.**

***Index Terms*— multihop, sparse infrastructure, Manhattan**

I. Introduction

Tradition cellular communication systems are designed to provide voice communications. During a phone call, interlocutors do not tolerate delay and interruptions while talking. Therefore, in order to minimize or avoid interruptions in some uncovered areas, cellular systems are designed to provide a high coverage, making a phone call possible at "every time and everywhere". Mobile terminals are getting more and more sophisticated and will allow services (such as pictures exchanges) which may require higher data rates. Providing higher data rates with the same Quality-of-service (ubiquity of service) will increase even more the cost of such cellular systems. In order remain competitive or to get competitive quality/price rapport, mobile operators might want to reduce their expenditures.

Concerning costs in wireless infrastructures, [1] shows that a wireless infrastructure cost (C_{system}) can basically be broken down into the following factors :

$$C_{system} \approx c \cdot N_{AP} \approx c' \cdot N_{users} \cdot B_{user} \cdot A_{service} \cdot f(Q)$$

where N_{AP} is the number of access points (AP). Operators might not want to change the number of users (clients) (N_{users}) and the average data rate of the users (B_{users}) as it could be a way of charging, but they can lower their expenditures by reducing the service area covered $(A_{service})$, or the quality-of-service $(f(Q))$. In order to reduce those costs, one alternative is to reduce the density of AP, leading to a more sparse infrastructure, and adopting a multihop architecture, relying on other mobiles to transmit the information. Those mobiles should be able to store other mobiles' messages, forward those messages to other mobiles and deliver them when they get in the range of an AP. With the mobility of the users, the messages should easily spread to other users. This spreading over the whole network should increase the probability to deliver the message to an AP.

Multihop Capable Nodes (MCN) are terminals which can communicate with each other outside the coverage area of a AP by relaying. MCN can store messages and then forward them when they come within the communication range of a AP or another MCN. MCN can extend the AP coverage and, as it allows self-organization and self-configuration of multihop cells, this architecture could also provide a rapid and easy way to install and set up an infrastructure. A similar wireless concept called *Infostations* was proposed and studied in [2] and [3] . *Infostations* are low-power AP providing strong signal quality (and high data rate connections) to small disjoint areas. These concept allows the nodes to transmit at times with larger signal quality to get improved throughput but at the expense of *potentially larger delays*.

We consider the possibility of extending the memory of the nodes in order to increases the number of replicas of the message in the network. Increasing the number of replicas of the message in the network may increases the probability of successfully deliver the message to an AP and therefore reduce the delay. As the message needs to be diffused and replicated in other nodes memory, this will *require larger storage capacity* in the terminals, but it can be considered technically feasible taking into account the reduction of the cost and the size of memory (" Moore's Law"). However, if the nodes are far from the AP, or if there is only one node in the network, the message will have to be "physically carried" to the range of the AP, and the delay will remain important, relying on the mobility of the node. This means that the model will not be suitable for real-time or time sensitive applications. We will then consider no-delay sensitive applications such as email, files sharing or messaging.

One of the main drawbacks of such a system is the time needed to deliver a message, which will increase if the terminal is not moving or is not in the range of a AP or has no terminal in its neighborhood to transmit its message. Therefore we will measure the relative delay for each generated message to be delivered. Another drawback is the memory occupation in the terminals. As the messages will be spread to neighbors in the network, this could lead to an overflow. We will focus on determining a upper limit for the buffer size of the terminals during the whole simulation. These could be useful for dimensioning the buffer size of terminals using such a system. The number of hops performed by a message until it is delivered will give informations about how the message was delivered. If the message message was not delivered via hops from terminals to terminals, this means that it was *"physically"* carried by the terminal from the place it was generated until the terminal came in the range of a AP. From this perspective, the mobility of the terminals will influence the delay to deliver the message. In the case of "physical carrying", if a terminal moves faster, it will have bigger probability to meet an AP, and then deliver the message.

II. System model

A. Environment model

In this paper, we limit the study to an urban area modelized by a Manhattan grid. The area is wrapped around North-South and West-East and the grid is composed of 10 by 10 blocks (buildings). The blocks are 200 meters wide and the streets are neglected for simplifications (Fig.1). The AP are randomly placed at the cross-points of the streets (only one AP possible per cross-point). The radius of the coverage for an AP is 100 meters and 50 meters for a MCN. We neglect the slides effects by assuming that terminals (MCN to MCN, or MCN to AP) can communicate only if they are on the same street and within the communication range described above.

B. mobility model

The MCN's are divided in two groups depending on their speed : a "pedestrian" group with a low speed and a "vehicular" group with a higher speed, in order to estimate the influence of the speed, as seen above. The pedestrian group of users is moving with a normal distributed speed with a mean of 3 km/h and a standard deviation of 0.3 km/h [4]. The vehicular group of users has also a normal distributed speed but with a mean of 50 km/h and a standard deviation of 2.5 km/h. At each cross-road, users of both groups have can either continue straight with the probability Pr(straight) = 0.5 or turn left/right with the probability Pr(right) = Pr(right) = 0.25.

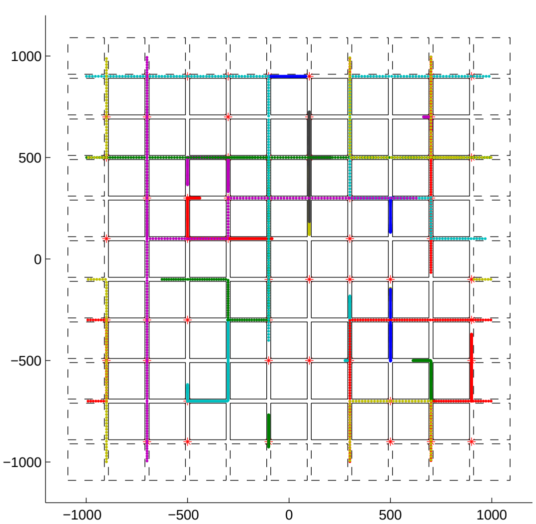

Fig. 1. Example of the Manhattan Grid Area

C. Traffic model

We assume that the packets are of constant length and arrive according to a Poisson process with total (external) rate λ. For N MCN's in the network, each MCN generates packets with the rate :

$$\lambda_i = \frac{\lambda}{N}$$

No considerations are made about the fragmentation of the data or on the packets size optimization. The packet is refereed as unit.

D. Memory management - Algorithm of multihops

For the simulations, the terminals have an infinite buffer (so that they could theoretically store all the messages generated during the simulation), but in fact when two terminals are close enough to communicate, they only exchange the messages which are not already in their own buffer. This limits somehow a potential buffer overflow risk. As well, when a terminal is in the range of a BS, it delivers all the messages stored in its buffer.

III. Performance measurement - Metrics for the results

A. the relative delay

The criteria selected for a successful transmission of a message is when the message is delivered to an AP. The delay is measured as relative time for each message, this means the time taken from its generation at the MCN's side to its successful delivery at a AP's side. The PDF, CDF and percentile for a given QoS requirement are computed from these relative delays.

B. the maximum buffer occupation

During the whole time of simulation, the maximum buffer occupation is recorded for each MCN. These maxima include delivered and non-delivered packets. From these maxima, we compute the PDF and CDF and deduce a maximum buffer size to provide a given QoS for delivering the packets.

C. the number of hops

For each successfully delivered packets (packets delivered to an AP), we record the number of hops performed by the replica which first reach an AP. We assume that the replicas which remains in other MCN's buffer are erased, so that they do not delivered twice and they are not taken into account in the maximum buffer occupation computations.

IV. Simulations

For a fixed messages arrivals density $\lambda = 6\,msg/min$, the simulations are performed during 1 hour. The AP density varies so that we get a coverage from 5% to 95%, and computed as :

$$\frac{4 \cdot number\,of\,AP\ \cdot\ range\,of\,an\,AP}{total\,length\,of\,the\,streets\,in\,the\,area}$$

For each of these AP densities, three users densities were studied (20, 50 and 100 users). The two users groups "pedestrian" and "vehicular" are assumed equal. The QoS requirement for the relative delay is fixed to 95% of successful delivery of the packets generated. The QoS for the number of hops performed is also 95% but of the packets delivered via multihops.

V. RESULTS

The results presented here are averages from 7 simulation runs. Each of the graph contains curves for the three users densities studied in order to simplify comparisons. On the x-axis in each graph, the coverage in percentage can be found.

First, we investigate the relative delay as shown in Fig. 2). This graph represents the time needed to deliver 95% of the messages generated during the simulation. It is easy to see that the density of users has a significant influence on the relative delay, the relative delay is longer for low density of users. This could be explain by the fact that with lower user density, each user has less chances to come in the communication range of another user, this means from the message point of view, less opportunities to spread or less opportunities of multihops. The other observation is for each users densities, the relative delay for very low density of AP is nearly twice the one for highest density, which is quite intuitive: the higher the AP density is, the higher are the chances for each moving users to get into the range of an AP and deliver all its messages in its buffer.

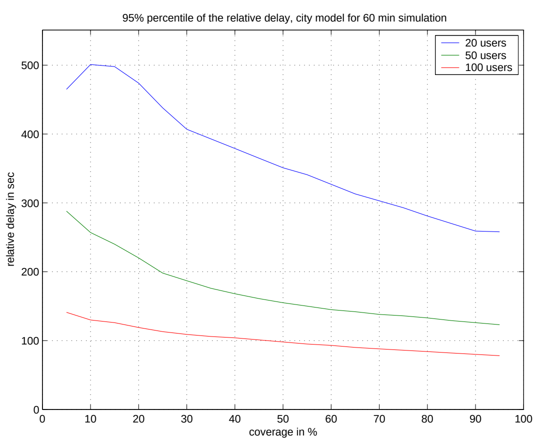

Fig. 2. 95% percentile of the relative delay

Looking at the maximum buffer occupation graph in Fig. 3), it seems that increasing the users density increase also somehow the maximum buffer occupation. This is because a higher density of users provide a better spreading of the messages over the network. A single user has then more chances to collect other users messages and then get a higher buffer occupation. This upper limit of maximum buffer is very influenced by the AP density, it is multiplied by a factor of 4 to 5 when passing from high to low AP densities. The obvious consequence is that the design of the terminal memory will be very dependant on the coverage area.

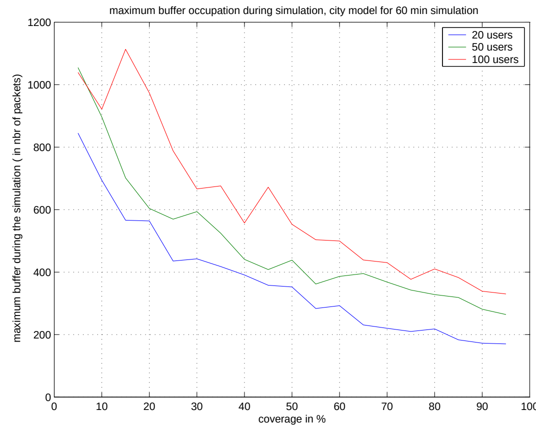

Fig. 3. Maximum buffer occupation during the simulation time

Finally, looking at the graph Fig. 4), we can see that the number of hops to deliver a message increase with the density of users. If we observe the results for low AP density, we can see that the number of hops to deliver the message is quite high (4 to 6 hops). This can be explain by the fact that the message is not "physically" transported by the motion of the users but is going faster by performing multihops from terminal to terminal until it reaches an AP. The other observation is that the number of hops performed is not higher than 6 for 95% of the messages delivered by multihops. This value can help to fix a "maximum number of hops to live" for the messages.

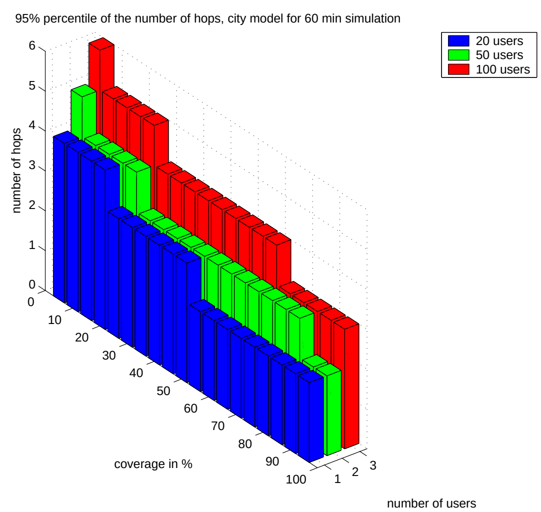

Fig. 4. 95% percentile of the number of hops

VI. CONCLUSION

In this paper, we studied the relative delay to deliver a message, a upper limit of the buffer occupation of the terminals, and the number of hops a message has performed when successfully delivered in a Manhattan environment for three different users densities and varying AP density. Simulations shows that communications using the mobility of multihop capable nodes and a low access point density is feasible but the service provided will suffer from a longer delay. In addition to that, the terminals memory capacity is very sensitive to the environment topology (AP density). For low AP densities, the

QoS depending on the delay is better for higher users density but at the expense of terminals with higher memory capacities.

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