Evaluation and optimization of the quality perceived by mobile users for new services in cellular networks

Phd subject proposal

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1 Global context

There is a need for simple, yet realistic methods for evaluation of *quality of service* (QoS) in *wireless networks* capturing both the spatial distribution of the elements of the network and the temporal dynamics and having a limited number of parameters. This can be obtained via modeling based on *probability theory* and more specifically on *queuing theory* and *information theory*.

The probabilistic setting reflects the network variability in time and space; this is particularly relevant for wireless networks. The modeling approach consists in representing the configuration of users (positions, call durations or volumes, allocated resources) as a random object (point pattern with associated random variables) which evolves in time. Thus the temporal evolution of the configuration of users may be viewed as a realization of a stochastic process.

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The quality of service perceived by the users may then be expressed as a function of the stationary state of this process and thus will depend only on its distribution parameters. This approach often allows for an explicit evaluation of the key characteristics such as users QoS and for efficient optimization of the network cost and capacity. Some examples from other research works which prove the pertinence of this approach, can be found in [4], [7], [2], [6], [3], [1], [5].

2 Positioning of the subject

The performance of wireless cellular networks is often evaluated in terms of parameters such as the spectral efficiency (in particular within 3GPP) or the outage probability (in some academic research). However from an operator's point of view, its is important to calculate the QoS perceived by the users; and in particular to relate this QoS to the key network parameters such as the traffic demand, the cell radius, the transmitted power, etc. This relation is crucial for the network dimensioning; i.e., evaluating the minimal number of base stations assuring some QoS (for some given traffic demand). This permits in particular to minimize the network cost.

The probabilistic approach described in the first section often allows for an explicit evaluation of the key characteristics such as users QoS and for efficient optimization of the network dimensioning.

3 Thesis Objectives; Expected Results; Scientific challenges

Classically, the services are classified into two main categories:

- Variable bit-rate (VBR); e.g., mail, ftp. Users aim to transmit some given volume of data at a bit-rate which may be decided by the network
- Constant bit-rate (CBR); e.g., voice, video conferencing. Users require some given (constant) bit-rate for some duration. In this case the requested bit-rates may sometimes exceed the available capacity, a situation usually called congestion. CBR services do not tolerate temporary interruptions of their transmissions. Consequently, if congestion occurs,

the network blocks (i.e., refuses the access to) new calls and drops (i.e., interrupt definitely) some others during their transmissions.

When we account for calls' arrivals, mobility and departures, the QoS perceived by the users (in the long run of the network) is different for each of the above traffic classes. For VBR connections, the QoS may be defined in terms of the mean throughput or delay per user. For CBR calls, the main QoS indicators are the blocking and dropping probabilities. The research done in the few last years permitted to build rapid and efficient methods to calculate these QoS indicators (see for example [6]). These methods are based respectively on processor sharing for VBR and on multi-Erlang models for CBR services.

However, new multimedia services are gaining interest in wireless cellular networks, especially streaming services. Streaming connections require some given bit-rate for some duration. Thus congestion may occur (when the bit-rates requested by the users in the network exceed the available capacity). All streaming calls are admitted, but, as a counterpart, they tolerate temporary interruptions of their transmission. We distinguish two sub-classes:

- Streaming-RT (Real-Time): e.g., mobile TV, RTP streaming. When congestion occurs, the corresponding portions of some calls are definitely lost, but the call is not dropped.
- Streaming-NRT (Non-Real-Time): e.g., streaming-video (youtube, dailymotion, on demand video) on the web. When congestion occurs, the corresponding portions of calls are delayed.

For the streaming users, the QoS is related to frequency of the interruption of their calls and the durations of these interruptions. These performance measures depend tightly on the mobility of users, as mobility increases the variability of the radio conditions. There is no rapid and efficient method to evaluate these parameters till now. The main objective of the thesis is to build such methods and integrate them within the global radio access dimensioning approach of Orange. This includes studying a mix of these services with classical VBR and CBR services, and calculating the perceived QoS by users. Optimal network dimensioning for a target QoS is also to be proposed.

4 Methodological approach

QoS evaluation may be decomposed into three sub-problems corresponding to different time-scales: information theory, resource allocation and queuing theory. Firstly, information theory gives the performance of a single radio link accounting particularly for the signal variations due to multi-path fading. Once the link performance is characterized, resources (power, bandwidth, bit-rate) are allocated to the users while accounting for their mutual interference. Finally, queuing theory accounts for the users' arrivals, mobility and departures.

Individual elements of the above puzzle (i.e. information theory, resource allocation and queuing theory) are often studied and optimized separately. The main specificity of the methodology proposed in this thesis is a global approach that combines these elements. In doing so, it is necessary to separate carefully the times scales of different elements of the network dynamics.

5 Global planning

The thesis will be carried at France Telecom, Research and Development Division (38/40 rue du Général Leclerc, 92794 Issy-Moulineaux). It will begin in October 2011 with the following steps (whose order and content may be reviewed/completed with the thesis directors if necessary):

1. A bibliographical study will be carried (3 months), and the existing models of CBR and VBR services are collected.

2. A model will be proposal for streaming-RT traffic (blocking and dropping), without mobility (~6 months).

3. Introduction of the mobility in the evaluation of streaming-RT (~6 months).

4. Study of the streaming-NRT, with and without mobility (~6 months).

5. Development of a capacity analysis method with a mix of CBR, VBR and elastic calls, with different priority schemes (~9 months).

6. Thesis writing and results consolidation (6 months).

6 Academic partnership

Bartlomiej Blaszczyszyn (INRIA and ENS ULM ; http://www.di.ens.fr/~blaszczy/).

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