TD INF567

Cellular Mobility

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1 Radio Procedures

The radio procedure 1 shown in Figure 1 has been inspired by the 3GPP standard 23.272 and the radio procedure 2 shown in Figure 1 has been taken from "Réseaux GSM", X. Lagrange, Hermes.

Question 1 *Which are the services described in these flow diagrams? It is not required to describe all message exchanges.*

2 Handover: An Analytical Study

We consider a GSM network in which new calls arrive according to a Poisson process, call duration, X, follows an exponential distribution with parameter μ. A new call arriving in a cell, where there is no traffic channel available is blocked (or rejected). The blocking probability P_b is an important parameter of the quality of service perceived by users.

We have seen in the lecture that a handover implies the release of a traffic channel in the originated cell and the establishment of a traffic channel in the target cell. The handover failure probability P_{hf} is the probability that the handover request in the target cell is rejected because no traffic channel is available. It is generally preferred to block new calls rather than dropping on going ones.

2.1 Blocking and Failure Probabilities

Let us assume that in a cell of reference, new calls arrive with rate λ_i and handover requests with rate λ_h, the call duration in the cell, X_c, follows an exponential distribution with parameter μ_c. There are m available traffic channels.

Assume first that handover requests and new calls are processed indifferently: at every new arrival or request, a traffic channel is allocated whenever there is one free.

Question 2 *What is the blocking probability P_b? What is the handover failure probability P_{hf}?*

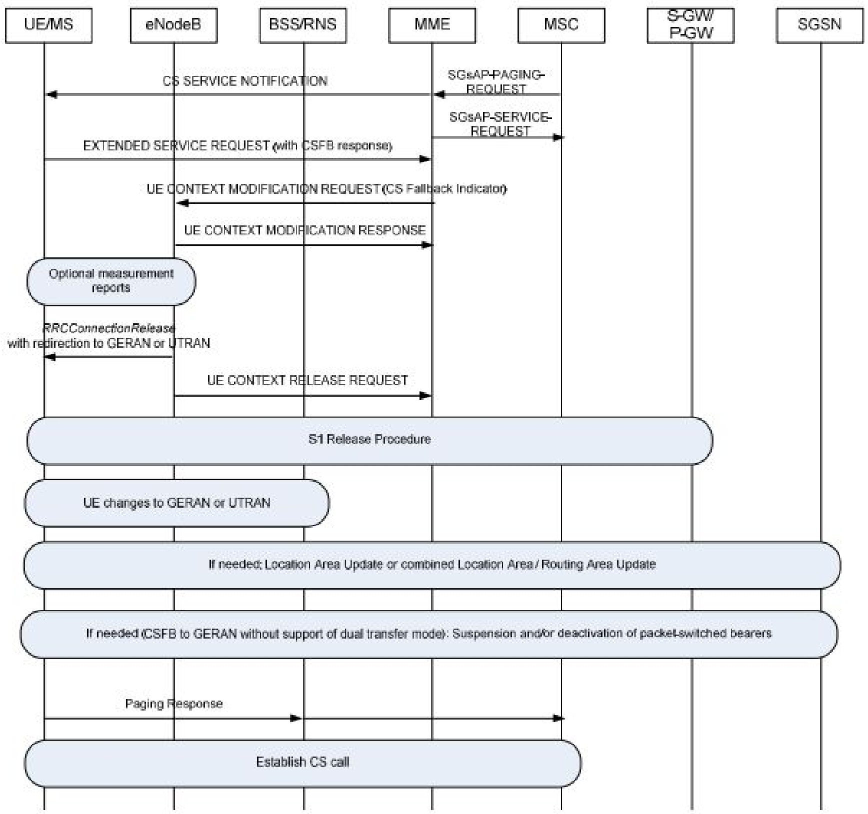

Figure 1: Radio procedure 1.

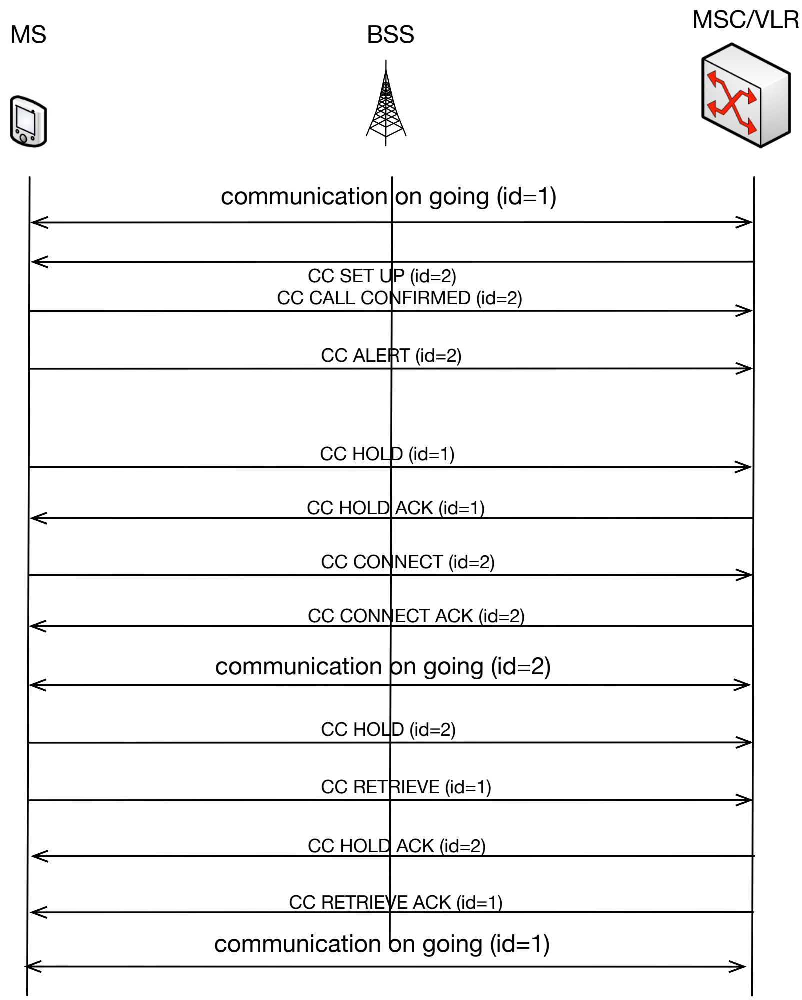

Figure 2: Radio procedure 2.

We now want to favor handover requests and we reserve g slots on which they have strict priority. We set $m = c + g$. As long as there are less than c channels occupied, new calls and handover requests are served as before. When there are c slots occupied, new calls are blocked whereas handover requests continue to be served if there are free channels. We denote: $\rho_i = \lambda_i/\mu_c$ and $\rho_h = \lambda_h/\mu_c$. Let $\{n(t)\}_{t\in\mathbb{R}}$ be the Markov process (or continuous-time Markov chain) representing the number of occupied channels.

Question 3 *Give the representation of the Markov process and derive stationary probabilities using border equations. (Recall that across the borders, flows in both directions are equal). Express P_b and P_{hf} as functions of the stationary probabilities.*

2.2 Handover Request Rate

We now want to express previous parameters as functions of traffic intensity and user mobility. In particular, λ_i and λ_h are interdependent and related to the time spent in a cell by a typical user. Let define X_h the time spent by a user in the cell, an exponential random variable with parameter η.

Question 4 *Express X_c as a function of X and X_h. Deduce from this the average call duration in the cell $1/\mu_c$ as a function of η and μ.*

Question 5 *Give the probability P_h that a call requires a handover. What is the average number of handovers per call ν?*

Question 6 *Explain why we have: $\lambda_h = P_h(1-P_b)\lambda_i + P_h(1-P_{hf})\lambda_h$. Deduce λ_h as a function of λ_i.*

Unfortunately, λ_h now depends on the probabilities we are looking at, P_b and P_{hf}.

Question 7 *In the general case, propose an iterative method to find P_b and P_{hf}. Proof of convergence is not required.*

Question 8 *In practical cases, P_b and P_{hf} are small. Compute in this case an approximation for λ_h as a function of λ_i and ν.*

2.3 Dropping Probability

Handover failure probability is not a measure directly related to the user experience. We thus define the dropping probability as the probability for a call to be dropped because of a handover failure (i.e., even after successive successful handovers).

Question 9 *Express the dropping probability P_d as a function of P_h and P_{hf}. Assuming that P_{hf} is small, express P_d as a function of P_{hf} and ν.*

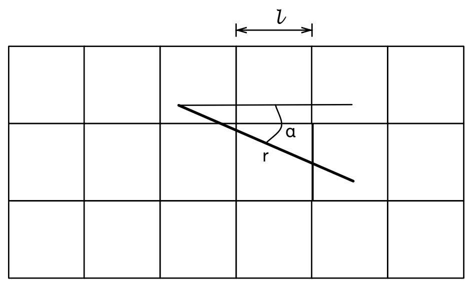

Figure 3: Cellular network and mobile user.

2.4 User Mobility

To simplify the analysis, we consider square cells of side length l as shown in Figure 2.4. A user travelling along a straight line over a distance r in the direction α at constant speed V changes cell γ times, where γ is the sum of crossed horizontal and vertical lines (i.e. cell borders).

Question 10 *Assuming that all directions are equiprobable, express $\bar{\gamma}$, the expectation of γ, as a function of r and l and deduce that $\eta = \frac{4V}{\pi l}$.*

3 Location Area Size Optimization

There is a well known tradeoff in the dimensioning of the location areas in cellular networks. Increasing the size of the location areas increases the signalling traffic in terms of paging, while decreasing the signalling traffic in terms of location area updates.

Let consider a cellular network with square cells as shown in Figure 2.4. Location areas are made of square regions made of $k \times k$ cells. We denote C_p the cost related to paging (in bytes/paging/cell), C_u the cost related to location update (in bytes/update), λ the rate of new calls per user (in calls/hour/user) and u_k the location area update per user (in number of updates/hour/user) when location areas have size $k \times k$ cells. Let ρ be the user density and V (in m/hour) the speed of users.

Question 11 *Express the signalling cost $C_s(k)$ per hour and per user as a function of the above parameters when location areas have size $k \times k$ cells.*

Question 12 *Using the same methodology as in section 2.4, derive the average number of users going out of the location area per hour and deduce u_k as a function of V, k and l.*

Question 13 *Show that there is a single optimal location area size k^* and study the (qualitative) variations of k^* with V, C_u/C_p, λ and l.*