Stretchable Architectures for Next Generation Cellular Networks
Topic: Wireless Networks

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Abstract—This paper examines the problem of conserving energy in 3G cellular systems by allowing calls between a mobile and the base station to be forwarded by some other mobile in the cell. This "stretched" call has the benefit of reducing overall energy cost for the call as in cases where the calling mobile is NLOS (Non Line of Sight) to the base station but is LOS to the intermediary and the intermediary is LOS to the base station. The main contributions of the paper are twofold: first, we show how this stretched call model can be implemented in UMTS and CDMA2000; second, we show that this stretched call model results in overall energy savings in a cell of between 2x and 7x.

A new technique to enable power savings at the Mobile Terminal (MT) and also to minimize the system energy is specified in this paper. The key idea is to split the connection between the MT and Base Station (BS) at an appropriate intermediary (another MT). Thus, on the reverse link, the MT transmits to the intermediary and the intermediary forwards the call to the base station. This *stretched* call model ensures that the total energy used for the call is less than that of a direct call if the intermediaries are selected appropriately. The problems involved in deploying such a stretched call model like intermediary-to-intermediary handoffs, preserving end-to-end encryption, maintaining closed-loop power control at the MT and the intermediary, handoffs between intermediaries are tackled in this paper. We present results from detailed simulations of our model and show that energy savings of as much as 2x to 7x is possible in many cases even when using a simple greedy algorithm for intermediary selection.

Results

For an evaluation of our stretched call model, we used the following metrics:

- Total energy used during a run of 1000s (*direct calls* between MT and BS or *stretched calls* where the intermediary is selected using the greedy algorithm). We also show the energy used per node.
- Number of handoffs between intermediaries.
- Percentage of time the calls were stretched as a function of number of MTs.

The figures shown in this abstract are results for the case when the *BS was located in the center* of the cell. The first figure shows the total system energy as a function of the number of nodes in the cell for two different call rates. As can be seen, higher call rates consume more energy. However irrespective of call rates the stretched model consumes less energy as compared with the direct model. *For a call rate of 1, the savings are greater than 50%, while for a call rate of 2 the savings vary from 3x to more than 7x.* Also the spread in confidence interval is less for stretched system.

We ran similar experiments when the *BS was in a corner* of the cell (this is a realistic scenario where the BS covers the cell using sectored antennas). On comparing with the case when the base station was at center of the cell, it is seen that for higher number of nodes, more energy is being spent. This is because the distance to the base station has increased thus directly impacting the energy of the direct or stretched call. In terms of savings, we see *energy savings of up to 4x* when using the stretched call model.

For both scenarios of BS at center and at corner, the percentage of time spent by a node with stretched connections, increases with the number of nodes as shown in the second figure. An important result is that, as the number of nodes increase, the percentage of carrying time of a node does not increase as much as the stretched time. Thus, the overhead on the intermediaries is minimal.

For both scenarios the number of handoffs are more at higher call rates. This is because at higher call rates for the same number of nodes, more MTs are actively placing calls and thus, if they are serving as intermediaries when a new call request arrives, the carried call will need to be handed off to another idle MT. Due to shortage of space, a figure showing handoff performance is not shown here.