Capacity Unbalance and Its Implication in Migration Strategies from Narrowband CDMA to Wideband CDMA

Dongwoo Kim* · Jong-Tock Kim**

* Center, Shinsegi Telecomm Inc.
** Korea Institute for Defence Analyses

Abstract

The code division multiple access(CDMA) is becoming a promising radio access technology for current and future mobile communications networks. While the main service of the current CDMA networks [1]-[2] is the voice communications, the next generation networks will provide multimedia services including voice and video telephony and wireless Internet access. In the evolution from the current CDMA networks toward the next generation networks, to guarantee the backward-compatibility with the existing infrastructure and mobile stations is one of the most important engineering issues. As an approach to accomplish this objective, the spectrally overlaid narrowband and wideband CDMA (N/W-CDMA, or respectively N-CDMA and W-CDMA) has been widely studied in [3]-[4]. Especially, overlaying W-CDMA with spreading bandwidth over 5 MHz on present 1.25 MHz narrowband cellular/PCS CDMA can be a practically meaningful choice [5].

In [5] and [6], the uplink and downlink capacities of the overlaid system are respectively examined. Since there is considerable asymmetry between uplink and downlink conditions [7], those capacities are unequal and either of two links determines the whole system capacity. In the following, this is referred to as the "capacity unbalance" [8]. If the capacity unbalance exists, a call attempt can be blocked due to the lack of capacity in either of two links, even though the other link has enough capacity. In this paper, we identify a capacity unbalance problem and discuss its implication in migrating from N-CDMA to W-CDMA. Our stress is placed on the capacity-limiting factors that can be scheduled and managed by the network operators: composition of service classes and the evolving status from the conventional N-CDMA, which cause the connection capacity unbalance between uplink and downlink.

In CDMA systems, the capacity is usually defined as the sum of information bits that can be transmitted by each user within a unit of time period (e.g., a frame) with a given quality in each cell. Let us call the capacity in this sense the "transmission capacity." The limiting link in terms of

transmission capacity is generally determined by the other-cell interference, the multipath fading, the effectiveness of power control, and the physical layer adopted by a specific system: Note that the physical layer includes generation, synchronization, modulation, and coding of the spread spectrum signals at the transmitter (and the inverse functions at the receiver) [7].

Another measure of capacity is the maximum number of users that can be simultaneously accommodated also with a given quality in each cell. Let us call the capacity in this sense the "connection capacity." In the present CDMA systems for voice communications, since each user transmits at the same (average) rate on both uplink and downlink, the connection capacity shows a similar result to the transmission capacity. In this case, the greater the transmission capacity is, the more connection capacity can be achieved. Thus, if the uplink is a limiting one in terms of the transmission capacity, it is the same for the connection capacity.

However, the situation may change in the future mobile communications environments where the traffic volume on the uplink can differ from that on the downlink. For example, let us consider Internet access, electronic newspaper, or mobile computing [9]. In general, since the mobile station tends to become a small and light one, the information database and the computing power for multimedia services would be located at the network side rather than at the mobile station. Thus, in the above-mentioned applications, short commands (typically, several tens of bytes) are transmitted via uplink, whereas relatively large files (typically, several tens or hundreds of kilobytes) are transmitted via downlink. In this case, the connection capacity can be limited by the downlink although two links have the same transmission capacity[8]. This, in turn, results in the waste of bandwidth and the degradation in the overall capacity. For example, if the uplink traffic volume is 20% of downlink one under full load condition, 80% of uplink bandwidth (and, eventually, 40% of the overall system bandwidth) is wasted.

In the aspect of traffic unbalance, two types of multimedia applications coexist: some applications (e.g., Internet access) cause that the utilization of radio resource is strongly biased toward the downlink (link-biased type), while others (e.g., voice and video telephony) require a similar bandwidth for both links (link-unbiased type). If the former traffic is a dominant one in a system, severe traffic unbalance between two links will occur. However, if the latter traffic is the major one, the unbalance will not be a serious problem. That is, the "composition of traffic classes" in a system may be one of the most important factors that directly influence the traffic unbalance. In this study, we assume that: in the N-CDMA system, the major traffic is voice and it is link-unbiased; and the W-CDMA system, there can be a mixture of link-biased traffic and link-unbiased traffic. Then the total traffic is link-biased and the degree of bias depends on the composition of traffic classes.

Since there are two different systems collocated in a spectrally overlaid N/W-CDMA network, the limiting link is not always determined uniquely. Instead, it changes depending on how much capacity is accessed in each system. In the beginning of the network evolution, N-CDMA is probably more utilized than W-CDMA. Then, the limiting link is mainly determined by N-CDMA system characteristics. However, as the network progresses and W-CDMA becomes prevailing, a different link could limit the capacity according to W-CDMA system characteristics.

As usually accepted in IS-95 CDMA network adopting 9.6 kbps as its maximum traffic rate [1], [10], the uplink often limits the overall capacity if the downlink power control is effective. When severe multipath fading, four adjacent cells or more, and bad spatial distribution of mobiles are confronted, the downlink gets worse and accordingly turns limiting. If the connection capacity is considered, the user activity plays the most important role in determining the limiting link of the future system. Moreover, the limiting link changes depending on the network evolution scenarios. If N-CDMA users are dominant in the initial stage of the evolution, the user activity discrepancy between uplink and downlink is not so serious in average and the overall capacity is limited by the uplink as in the previous system. As W-CDMA users increase, however, the downlink is going to limit the capacity. Thus, the network operators who intend to efficiently utilize the bandwidth should devote their efforts to forming services so that the overall activity discrepancy could be mitigated according to the network evolution. Related on our work in this paper, the asymmetric bandwidth allocation between uplink and downlink and CDMA/TDD are also interesting fields for future research.

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