Qualcomm Technologies, Inc.

Qualcomm Research

HSPA Supplemental Downlink

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Abstract

Supplemental Downlink (SDL) has been enabled inThird Generation partnership Project (3GPP) Release 9 as part of the evolution of High Speed Downlink Packet Access (HSDPA). While the serving carrier (cell) for an HSDPA UE is part of paired spectrum, the SDL carrier is part of unpaired spectrum in a different band. Thus, SDL operation helps efficiently utilize unpaired spectrum for HSDPA. 3GPP Release 10 extends SDL operation by bonding up to 3 carriers in the unpaired band with the serving carrier(s) in the paired band. The SDL carrier just needs to support the Primary Common Pilot Channel as overhead, thereby leaving a larger share of power for HSDPA channels. For these reasons, SDL deployments can provide significant gains in both the user experience and number of users supported for a given user experience, when compared to a Single Carrier (SC) deployment.

Introduction

The Third Generation Partnership Project (3GPP) has been working on enhancements to the Wideband Code Division Multiple Access (WCDMA) systems since Release 5. In Release 8, Dual Cell High Speed Downlink Packet Access (DC-HSDPA) was standardized, and it has been widely deployed worldwide. In Release 9, Dual-Band (DB) DC-HSDPA operation was standardized, which enables the Supplementary Downlink (SDL) feature. Release 10 extended DB-DC-HSDPA to a total of 4 carriers across the two bands, which enables the aggregation of up to three SDL carriers with a serving carrier in the paired band. The high demand for data capacity has prompted operators to look for additional spectrum, including unpaired, to augment Frequency Division Duplex (FDD) deployments in the downlink, where there is a bigger need due to inherent asymmetry of data traffic. The SDL scheme provides a simple way to add unpaired spectrum to the downlink of existing Single Carrier deployments.

The SDL carriers are configured in the unpaired band. As illustrated in Figure 1, up to three carriers from the unpaired spectrum can be bonded with one carrier in the paired spectrum for Release 10 capable UEs. As examples, the unpaired spectrum could be part of the L-Band (1425 MHz to 1492 MHz) in Europe or the 700 MHz band in the US. In this paper, we focus on the performance of SDL operations with a single and two SDL carriers.

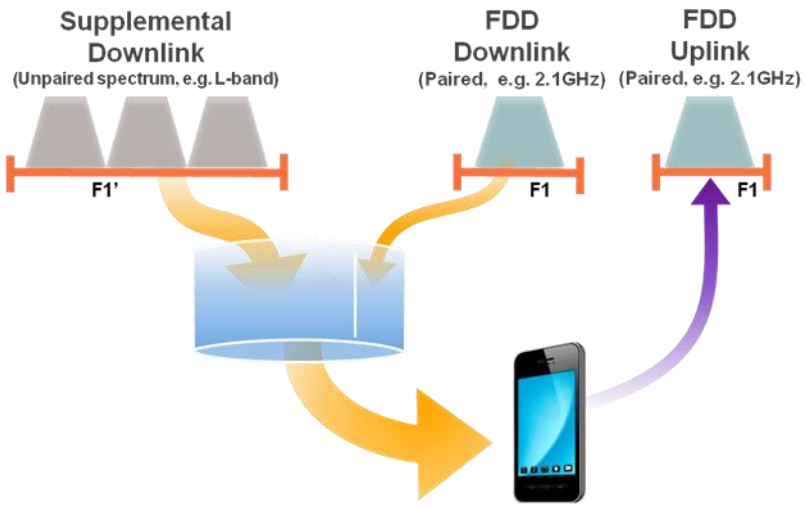


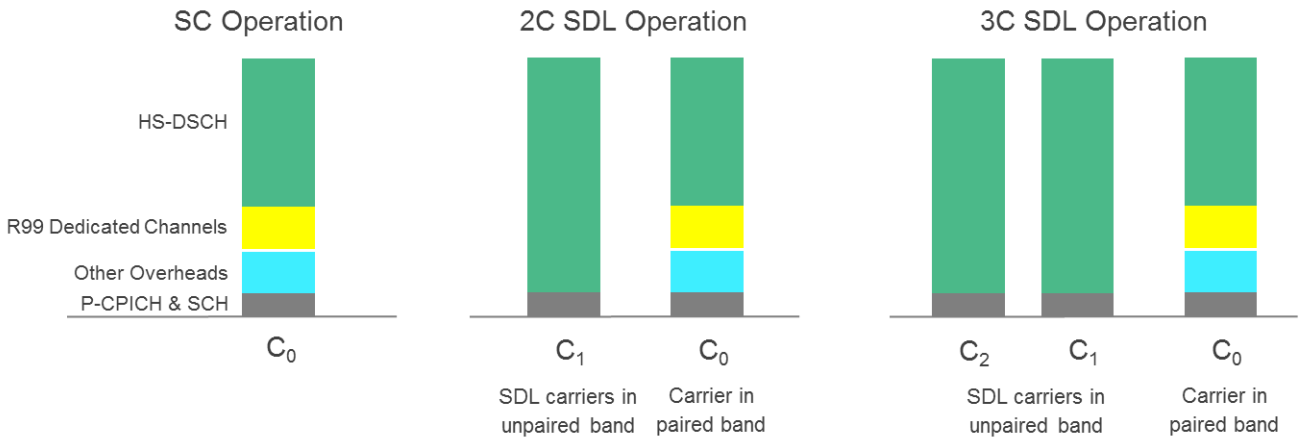
Figure 1: Supplemental Downlink Configuration

Since the SDL carrier is not paired with an uplink, it cannot support UEs configured in pre-Release 9 modes (legacy UEs). It can only be used as the secondary serving cell (carrier) by Release 9, or later, UEs. On the downlink, the SDL carrier just needs to transmit the Primary Common Pilot Channel (P-CPICH) and Synchronization Channel (SCH) as overhead and all remaining power can be used for High-Speed Downlink Shared Channels (HS-DSCH) transmission along with the associated control channels, and High Speed Shared Control Channel (HS-SCCH). On the other hand, carriers in the paired band need to assign power to other overhead channels, such as a Primary Common Control Physical Channel (PCCPCH), in addition to supporting Dedicated Release 99 channels for voice calls. SDL operation therefore gives significant gains over single carrier (SC) operation.

Note that SDL operation is different from traditional Multi-carrier HSDPA. In Release 8 DC-HSDPA, both the carriers can support SC UEs as well as DC-HSDPA UEs. Hence, the Radio Network Controller (RNC) can assign an SC UE to either of the two carriers. In contrast, the SDL carrier cannot support single carrier (pre-Release 9) operation.

Figure 2 shows Single Carrier (SC) and SDL operations. If all the UEs in the system are configured in SC-mode, all user traffic (including R99, HS-DSCH) is transmitted through carrier C_0. If an SDL carrier, C_1, is available and Release 9 and 10 capable UEs are configured in SDL mode, they can be served on both carriers C_0 and C_1 under the Two-Carrier (2C) SDL scenario. If two SDL carriers, C_1 and C_2, are available and Release 10 capable UEs are configured in SDL mode, they can be served on the three carriers C_0, C_1 and C_2 under the Three-Carrier (3C) SDL scenario. The power available for SDL users more than doubles in 2C SDL and more than triples in 3C SDL scenarios (see green bars in Figure 2).

Figure 2 below: Power per channel differences between Single Carrier and SDL operations



Simulation

In this section, we explain the simulation setup. We compare the performance without (baseline) and with SDL operation to show the gains from the feature. To analyze the user experience gains, we hold the total number of UEs ("M" R99 UEs and "N" HS UEs) in the sector constant. All "N" HS users are assumed to be Release 10 capable. The baseline corresponds to all "M+N" UEs being served in the SC mode by the serving cell (carrier) C_0, as the SDL carrier cannot support SC UEs.

We also consider both the 2C SDL and 3C SDL scenarios. In the 2C SDL scenario, the "N" HS UEs are served by both carriers (i.e. C_0 and C_1). While in 3C SDL scenario, the "N" HS UEs are served by three carriers (i.e. C_0, C_1, and C_2). For both SDL scenarios, the "M" R99 UEs are served only by the serving carrier C_0. Note that as shown in Figure 2, power available for HS transmission is higher on the SDL carriers (C_1 and C_2) than on C_0. Table 1 contains the system simulation assumptions.

Table 1: System Simulation Assumptions

Parameter	Value
Layout	19 Node-Bs with 3 Cells/Node-B
Inter-Site Distance	1 km
Path Loss (dB)	$128.1 + 37.6\text{Log}_{10}D_{km}$
Antenna Pattern	Sectorized 2D pattern: $G = -Max\left[\left(\frac{\theta}{\theta_{3dB}}\right)^2, 20\right] dB,$ where $\theta_{3dB} = 70\ deg$
P-CPICH Power	10%
Total Overhead Power including P-CPICH	30% for Serving Cell (carrier) 10% for SDL Carrier
Channel Model	PA3
UE Receiver Type	Type 3i (LMMSE + RxD)
Traffic Type	Bursty Data (1 Mb burst arrives every "T" sec) T is exponentially distributed with a mean of 5 sec.
No. of R99 UEs/sector	16
R99 user power consumption	20%

In this section, we show performance gains with SDL. Performance gain can be measured in two ways: User Experience Gain and Capacity Gain for a given experience level.

Figure 3 compares the HS user experience of SC, 2C SDL, and 3C SDL. We define user experience as the mean rate at which a traffic burst is downloaded for a given HS UE. Figure 3 shows the mean of the user experience across all HS UEs, as a function of the number of HS users/sector. At a given number of HS users in the sector, the burst rate increases significantly by increasing the number of downlink carriers with SDL deployments (as shown by the vertical arrows). For example, at around 6 HS users/sector, the mean user experience gains for 2C SDL and 3C SDL relative to SC are more than 200% and 400%, respectively.

At a given user experience level, the number of supportable HS users increases significantly with SDL deployment. For example, in Figure 3, at a user experience of 4 Mbps, HSDPA can support 6 HS users in the baseline SC case, while it can support close to 27 HS users in 2C SDL deployments and 48 users in 3C SDL deployments. These represent capacity gains of more than 300% from SC to 2C SDL and 700% from SC to 3C SDL.

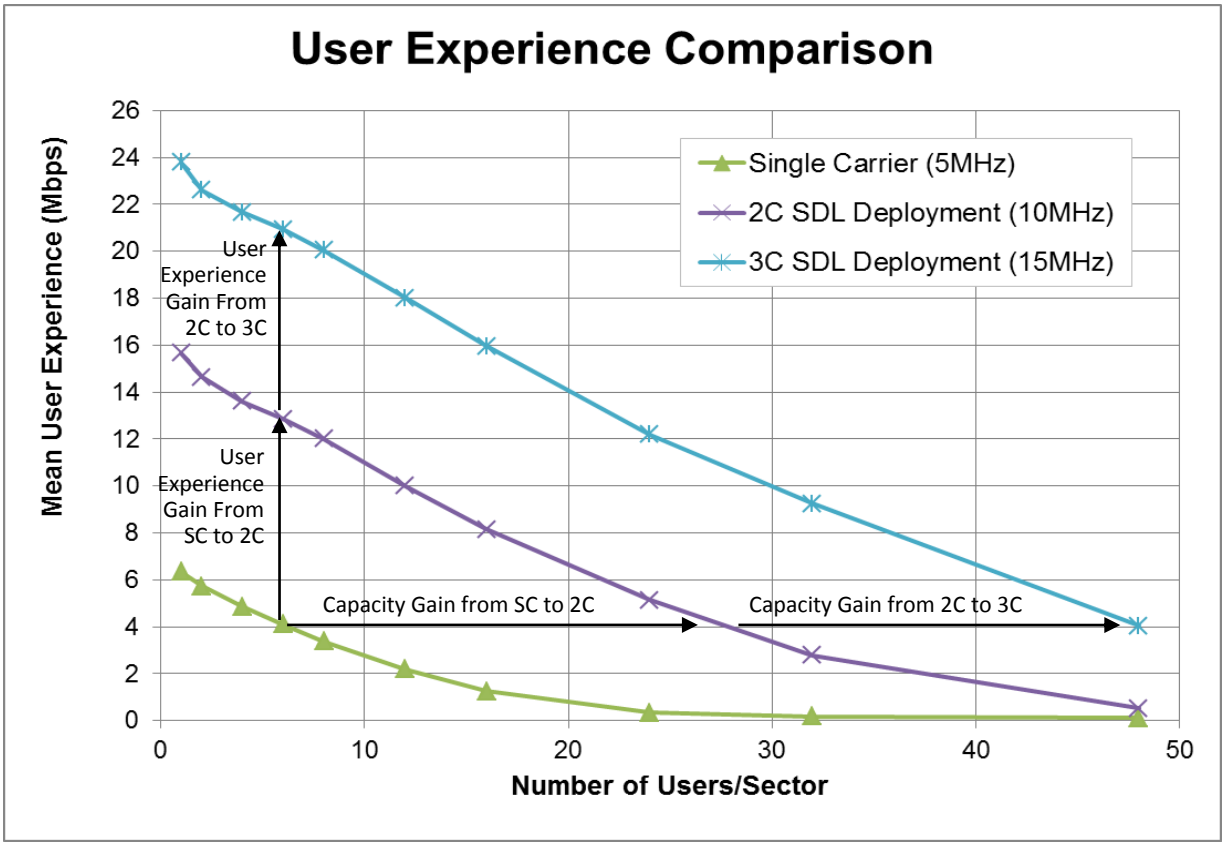
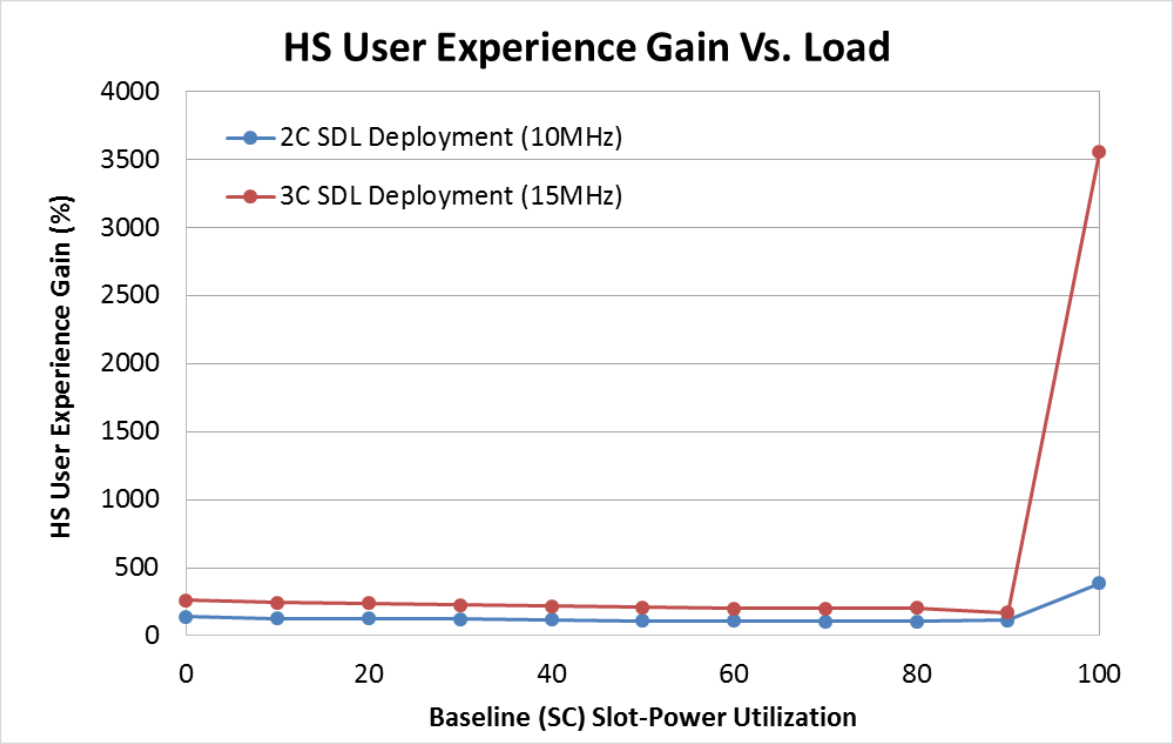


Figure 3: User Experience Vs. Number of HS Users/Sector for SC, 2C SDL and 3C SDL Scenarios

As the number of UEs/sector increases, the slot utilization increases and the baseline SC performance suffers. Deploying SDL in this cases prevents this from happening. For example, when the slot-power utilization approaches 100%, the baseline SC user experience is significantly degraded and the gains from 2C SDL and 3C SDL exceed 380% and 3500%, respectively. This effect is shown in Figure 4 below.



Conclusions

SDL operation allows the utilization of unpaired spectrum for HSDPA. Bonding of additional downlink carriers to an existing FDD carrier using Release 9 and 10 capable UEs, provides very significant user experience gains. These gains come from two areas. First, the multiplexing of bursty traffic on more than one downlink carriers results in a higher system capacity and better user experience. And second, the SDL carrier can assign greater power for HSDPA transmissions than carriers in the paired spectrum.

We have presented simulation results which show significant gains in user experience and the number of users supported for a given user experience. User experience gain with SDL deployment over the baseline SC system is always more than double for 2C SDL and more than triple for 3C SDL. The gain in the number of users supported for a given user experience is close to an order of magnitude at low loads.

Revision History

Revision	Date	Table heading
A	June 2011	First Version
B	June 2014	Reformatted
C	December 2014	Added 3C SDL results