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WHITE PAPER

WCDMA Evolved

The first step – HSDPA

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Preface

This white paper is primarily intended for mobile operators and telecommunications journalists and analysts. It describes the basic principles of HSDPA – High Speed Downlink Packet Access as part of the first step of WCDMA Evolved and the added value for operators and their end-users when HSDPA is implemented in a network.

Contents

1 Executive summary

WCDMA will be evolved to handle higher bit rates. The first step is to improve the downlink. WCDMA 3GPP Release 5 extends the specification with HSDPA, which is an enhancement of WCDMA. In the second step the uplink will be enhanced.

HSDPA improves the end-user experience by

- increasing peak data rates to 14 Mbps in the downlink;
- reducing delay; and
- providing 2-3 times more system capacity.

Through these capabilities, operators will benefit from a technology that will provide performance for improved end-user experience for web access, file download and streaming services. Wireless Broadband access to the Internet, intranet and corporate LAN will benefit greatly from WCDMA Evolved.

2 Introduction

As the penetration and use of packet-data services increases and new services are introduced, end-users will require higher data rates and improved quality of service (QoS). Operators will also require more capacity in their systems.

Terminals such as PDAs, smart phones and PCs with high-resolution color screens, larger displays and greater memory capacity will become more common, requiring greater speed and shorter delays when downloading audio, video and large files, or playing games.

WCDMA 3GPP Release 99 provides data rates of 384 kbps for wide area coverage and up to 2 Mbps for hot-spot areas, which is sufficient for most existing packet-data applications. WCDMA 3GPP Release 5 extends the specification with HSDPA.

3 WCDMA Evolved

The introduction of WCDMA follows a natural evolution of 2G networks. As with the introduction of 2G networks, early 1990, it describes the first step in a continuous evolution of technologies and what technologies can provide for end-users and operators. The term “WCDMA Evolved” describes the evolution of WCDMA addressing both operators need for efficiency and end-users demand for enhanced experience and simplicity. While the introductory phase is passed, end-user experience and enhanced system throughput is the focus of the first step of WCDMA Evolved i.e. HSDPA – High Speed Downlink Packet Access. Later, features to further enhance the uplink with improved coverage for high data rates, improved uplink capacity and reduced uplink delay will be part of the second step within WCDMA Evolved. Possible future steps are currently discussed and investigated within 3GPP. The following chapters will focus on the first step of WCDMA Evolved, HSDPA.

4 The concept of HSDPA

In WCDMA 3GPP release 5, WCDMA has been extended with a new transport channel, the high-speed downlink shared channel (HS-DSCH), which provides enhanced support for interactive, background, and to some extent, streaming radio access bearer (RAB) services in the downlink.

HS-DSCH transmission facilitates several new features. But to support them with minimum impact on the existing radio interface protocol architecture, a new MAC sub-layer, MAC-hs, has been introduced for HS-DSCH transmission. MAC-hs makes it possible to retain a functional split between layers and nodes from WCDMA 3GPP release 99.

A minimum of architectural changes allows a smooth upgrade to HSDPA and ensures HSDPA operation in environments where not all cells have HSDPA functionality.

HSDPA is based on “fat-pipe”, shared-channel transmission. Its key features are rapid adaptation to changes in the radio environment and fast retransmission of erroneous data, Therefore, the corresponding functionality must be placed close to the air interface.

The HSDPA concept is based on the following features:

- Shared channel transmission
- Higher-order modulation
- Short transmission time interval (TTI)
- Fast link adaptation
- Fast scheduling
- Fast hybrid automatic-repeat-request (ARQ).

The general principles behind these features are described below.

4.1 Shared channel transmission

HS-DSCH is based on shared-channel transmission, which means that some channel codes and the transmission power in a cell are seen as a common resource that is dynamically shared between users in the time and code domains.

Shared channel transmission results in more efficient use of available codes and power resources in WCDMA compared to the current use of a dedicated channel (WCDMA 3GPP Release 99).

The shared code resource onto which the HS-DSCH is mapped consists of up to 15 codes. The spreading factor (SF) is fixed at 16 (Figure 1). The actual number employed depends on the number of codes supported by the terminal/system, operator settings, and system capacity.

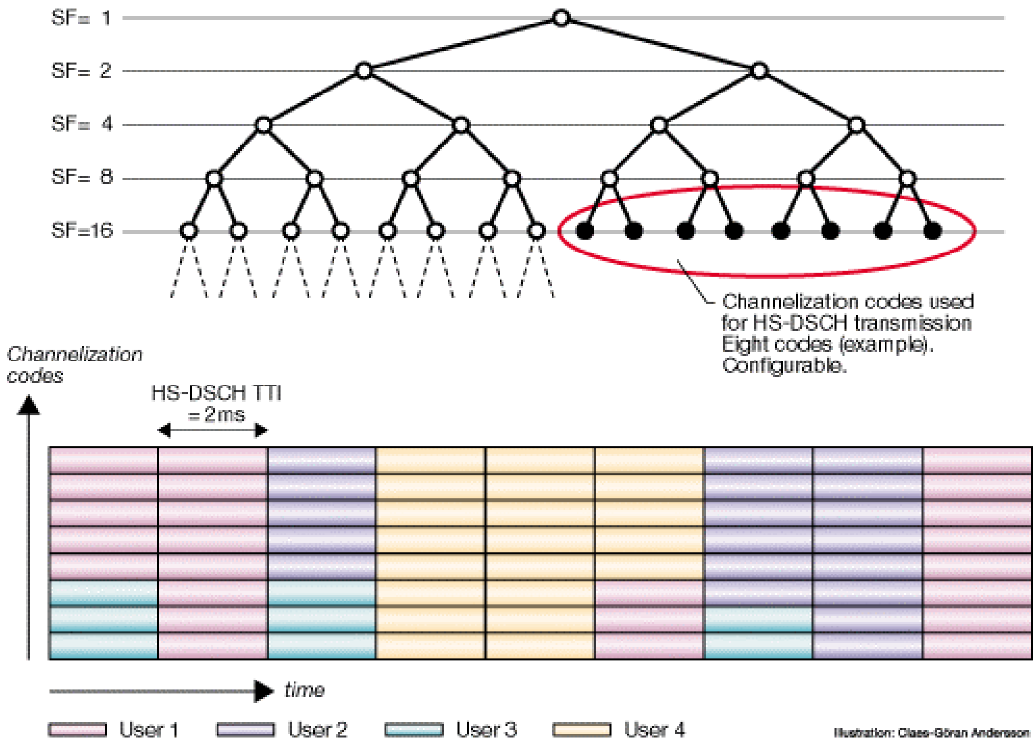

Figure 1. HS-DSCH code and time structures

4.2 Higher-order modulation

WCDMA 3GPP release 99 uses quadrature phase-shift keying (QPSK) modulation for downlink transmission. Besides QPSK, HS-DSCH can also use 16-quadrature amplitude modulation (16QAM) to provide higher data rates. Because 16QAM has twice the peak rate capability of QPSK it makes more efficient use of bandwidth than QPSK. Nevertheless, it also requires better radio channel conditions than QPSK.

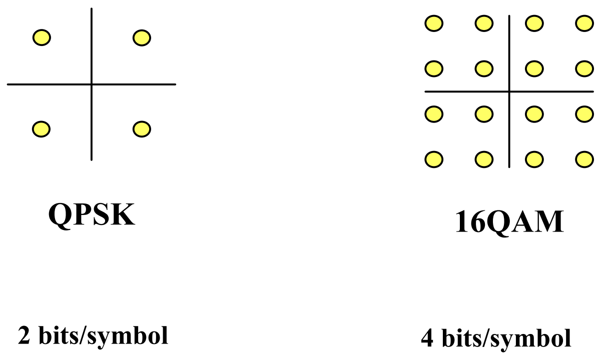

Figure 2. Modulation schemes used with HSDPA

4.3 Short TTI

Channel codes from the shared code resource are dynamically allocated every 2 ms or 500 times per second. A short TTI reduces roundtrip time and improves the tracking of channel variations—a feature that is exploited by link adaptation and channel-dependent scheduling. Although time is the primary way of sharing the "fat-pipe" resource among users, it is also possible to share resources in the code domain by using different subsets of the total HS-DSCH channel code set (Figure 1).

4.4 Fast link adaptation

Radio channel conditions experienced by different downlink communication links vary significantly both in time and between different positions in the cell. Fast link adaptation adjusts the transmission parameters to instantaneous radio conditions and, when channel conditions permit, enables the use of high-order modulations.

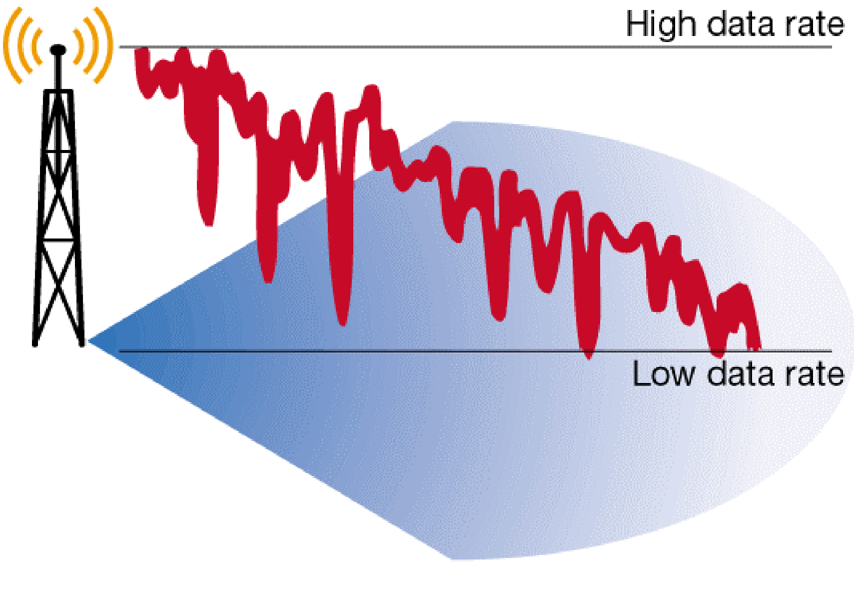

Figure 3. Transmission parameters adjusted to instantaneous radio conditions

WCDMA uses power control to compensate for differences and variations in the instantaneous radio channel conditions of the downlink. In principle, power control give communication links with bad channel conditions a proportionally larger part of the total available cell power. This ensures similar service quality to all communication links, despite differences in radio channel conditions. At the same time, radio resources are used more efficiently when allocated to communication links with good channel conditions. Thus, when seen in terms of overall system throughput, power control is not the most efficient means of allocating available resources.

Instead of using power control to compensate for rapidly varying radio conditions in the downlink, HS-DSCH relies on rate adjustment. That is, while keeping transmission power constant, it adjusts the data rate by changing the channel-coding rate. Commonly known as rate adaptation or link adaptation, this method is more efficient than power control for services that tolerate short-term variations in the data rate. What is more, to further increase peak data rates, HS-DSCH can use spectral-efficient 16QAM modulation when channel conditions permit.

4.5 Fast scheduling

The fast-scheduling feature determines to which user equipment (UE) the shared channel transmission should be directed at any given moment. The objective is to transmit to users with favorable radio conditions.

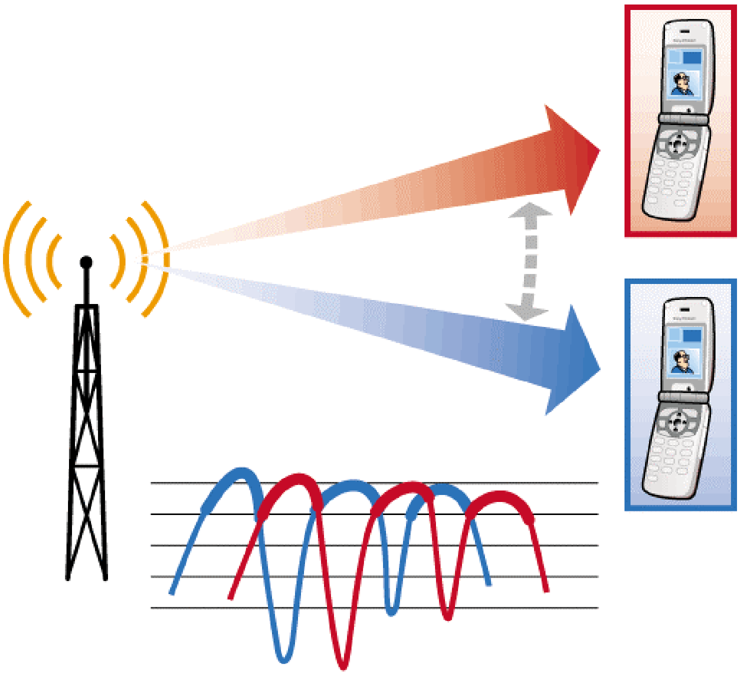

Illustration: Claes-Göran Andersson

Figure 4. Transmitting to users with favorable radio conditions

The scheduler determines overall HSDPA performance. For each TTI, the scheduler decides which users the HS-DSCH should be transmitted to, and in close cooperation with the link adaptation mechanism, which modulation and how many codes should be used. This yields the actual end-user bit rate. Instead of sequentially allocating radio resources among users (round-robin scheduling), capacity can be increased significantly using channel-dependent scheduling. The aim of channel-dependent scheduling is to transmit to users with favorable instantaneous channel conditions. The gain obtained by transmitting to users with favorable conditions is known as multi-user diversity.

Ericsson has chosen to use a proportional fair scheduler to better exploit the channel conditions and to ensure that all users receive a guaranteed minimum throughput.

As cell load increases, the number of users queued for scheduling increases. Therefore, the probability of scheduling users with good channel quality also increases. This typically results in a high carrier-to-interference ratio for the scheduled user. Traffic priorities can also be taken into account—for example, streaming services can be prioritized ahead of background users.

A practical scheduling strategy usually exploits short-term variations while maintaining some degree of long-term fairness between users. Long-term unfairness results in excess cell capacity. The differences between various scheduling strategies are most obvious when system load is heavy.

4.6 Fast hybrid ARQ

The UE can rapidly request the retransmission of missing data and combine information from the original transmission with that of the later transmission before attempting to decode the message. This approach, called soft-combining, increases capacity and provides robustness. A negative acknowledge (NACK) reply is sent when data is missing at the receiving end. An acknowledge (ACK) reply is sent when received data is correct.

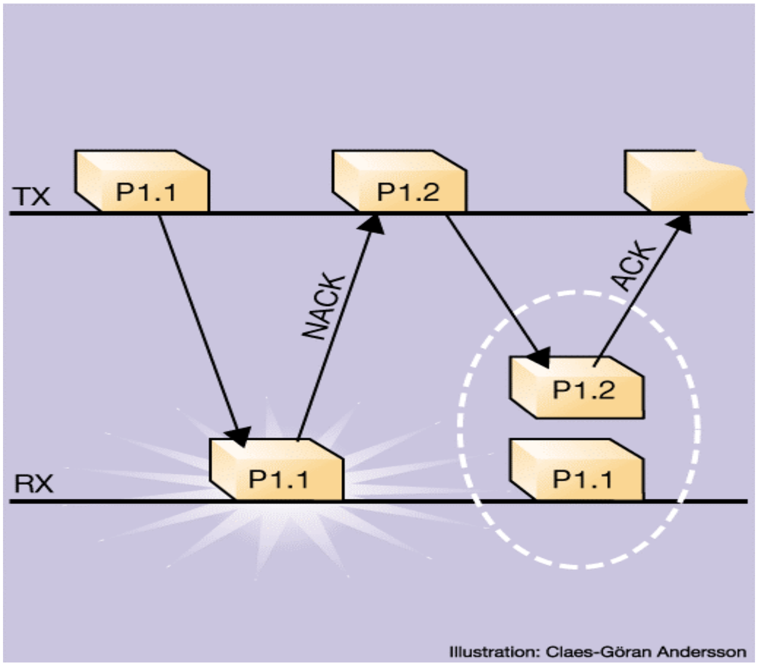

Figure 5. Rapid request of retransmission of missing data

5 Operators and end-users will benefit from the introduction of HSDPA

The primary benefit of HSDPA is **improved end-user experience**. In practice, this means shorter download times through **higher bit rates** (14 Mbps peak rate) and **reduced roundtrip time** over the air interface. HSDPA also provides advantages for operators by introducing **greater system capacity**.

5.1 Improved end-user experience

As in any system, end-user performance in HSDPA depends on type of service and the behavior of higher-layer application protocols. For instance, TCP, which is commonly used for packet-data services, was originally designed for wired networks and includes slow-start and congestion-avoidance mechanisms that strongly influence performance. A fair assessment of the overall performance of a particular service must include these mechanisms.

For web-browsing services, the perceived data rates are thus often limited by TCP and not the air interface. TCP transmission consists of sudden bursts of traffic followed by relatively long idle periods. Hence, system load from a user browsing the web is relatively light. The main end-user benefit of HSDPA for small objects transported via TCP is reduced roundtrip time thanks to hybrid-ARQ and short TTI.

In contrast to web browsing, the slow-start mechanism in TCP has little or no impact on the time it takes to download a large file. Instead, the perceived end-user performance is largely determined by the data rate of the radio link. A single user downloading a large file can occupy a significant amount of the total cell capacity. Consequently, system load has a substantial impact on the perceived performance when end-users download large files. Simulations show that in a lightly loaded system, HSDPA can reduce the time it takes to download large files by a factor of 20.

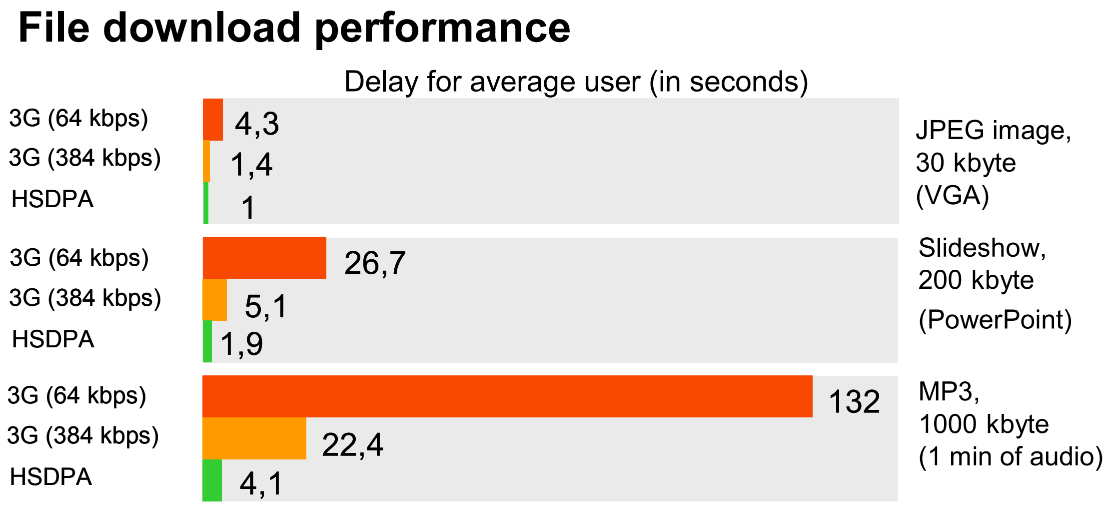

Figure 6. File download performance for different WCDMA data rates

HDSPA opens up for enhanced end-user experience when using WCDMA for **Wireless Broadband Applications** such as intranet and Internet access via laptop computers. Here the reduced delay improves the traditional web access. Download of emails and other heavy files are improved by the increased peak data rates.

5.2 Improved system capacity

A further benefit of HSDPA is **greater system capacity**. HSDPA increases capacity in several ways:

- Shared-channel transmission results in efficient use of available code and power resources in WCDMA.
- The use of a shorter TTI reduces roundtrip time and improves the tracking of fast channel variations.
- Link adaptation maximizes channel usage and enables the base station to operate close to maximum cell power.
- Fast scheduling prioritizes users with the most favorable channel conditions.
- Fast retransmission and soft-combining further increases capacity,
- 16QAM yields higher bit rates.

Depending on the deployment scenario, the combined gain in capacity is from two to three times that of WCDMA 3GPP release 99.

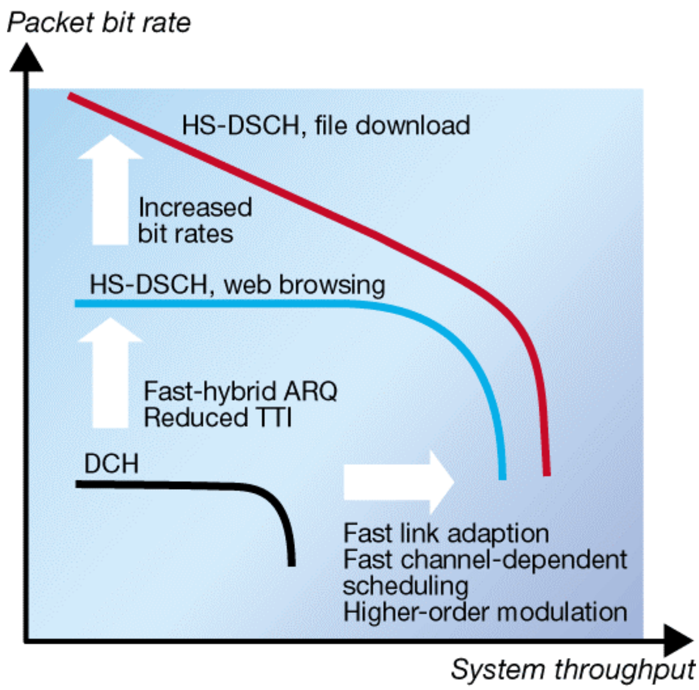

Illustration: Claes-Göran Andersson

Figure 7. Performance enhancements attributed to HSDPA

5.3 Integral part of WCDMA

Another benefit of HSDPA is that it is an **integral part of WCDMA**. Wide-area mobile coverage can be provided with HSDPA. It does not need any extra spectrum/carrier. At present, WCDMA can provide simultaneous voice and data services (multi-services) to users on the same carrier. This also applies to HSDPA, which means that spectrum can be used efficiently. HSDPA also makes efficient use of power (Figure 8) by employing unused power.

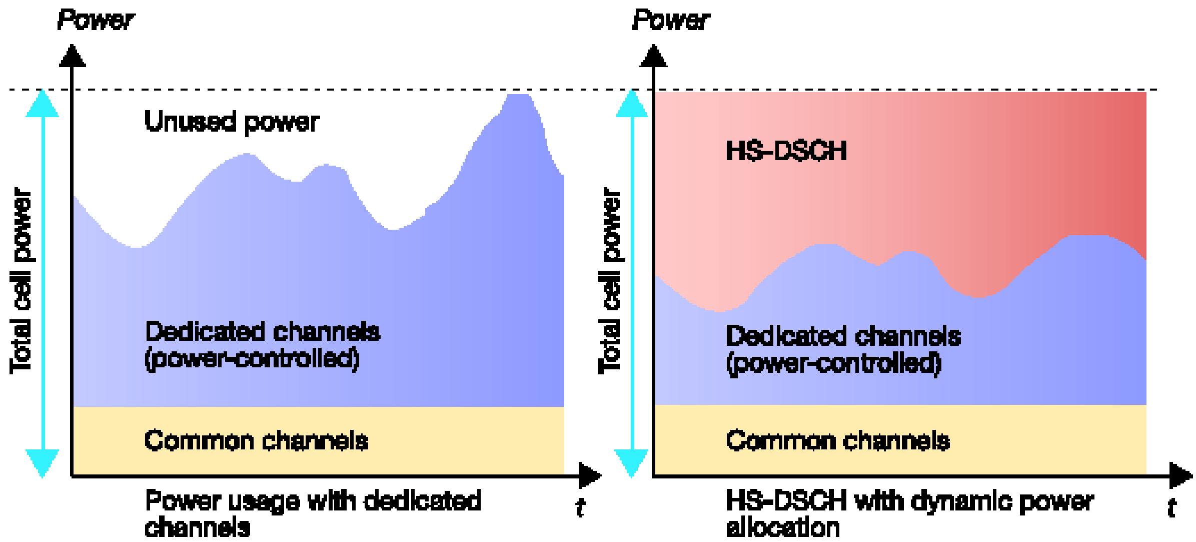

Figure 8. Power utilization with and without HSDPA

6 Summary

WCDMA will be evolved to handle higher bit rates. The first step is to improve the downlink in WCDMA. HSDPA will greatly improve the end-user experience by increasing bit rates to as much as 14 Mbps in the downlink, reducing delay, and increasing system capacity 200 – 300 percent.

No new spectrum/carrier is needed to roll out HSDPA in the network. At present, WCDMA can provide voice and data services on the same carrier simultaneously. This also applies to HSDPA.

With the advantages of HSDPA, WCDMA Evolved will further enable operators to provide end-users with more advanced Wireless Broadband applications offering wide area coverage and mobility.

7 Acronyms

16QAM	16-quadrature amplitude modulation
3GPP	Third-generation Partnership Project
ACK	Acknowledge
ARQ	Automatic repeat request
HS-DSCH	High-speed downlink shared channel
HSDPA	High-speed downlink packet access
MAC	Medium access control
NACK	Negative acknowledge
QPSK	Quadrature phase-shift keying
RAB	Radio access bearer
SF	Spreading factor
TCP	Transmission control protocol
TTI	Transmission time interval
UE	User equipment
WCDMA	Wideband code-division multiple access