**Evolution of LTE toward International Mobile Telecommunications (IMT)-Advanced**

**INTRODUCTION**

Release 8 can provide downlink and uplink peak rates up to 300 and 75 Mb/s, respectively, a one-way radio-network delay of less than 5 ms, and a significant increase in spectrum efficiency.

Support FDD, TDD, TD-SCDMA, HSPA and WCDMA.

The use of OFDM on the downlink combined with DFTSOFDM on the uplink thus minimizes terminal complexity on the receiver side (downlink) as well as on the transmitter side (uplink), leading to an overall reduction in terminal complexity

and Power consumption.

The transmitted signal is organized into subframes of 1ms duration with 10 subframes forming a radio frame.

Each downlink subframe consists of a control region of one to three OFDM symbols, used for control signaling from the base station to the terminals, and a data region comprising the remaining part and used for data transmission to the terminals.

**ITU AND IMT-ADVANCED**

IMT-Advanced is the term used by ITU for radio access technologies beyond IMT-2000.

As will be seen, Release 10 will not only fulfill the IMT-Advanced requirements but in many cases even surpass them.

**LTE RELEASE 10**

The evolution of LTE to further improve performance.

The most important of which carrier aggregation, enhanced multi-antenna support, improved support for heterogeneous deployments, and relaying.

It allows for smooth introduction of new technologies without jeopardizing existing investments.

**CARRIER AGGREGATION**

Release 10 the transmission bandwidth can be further extended by means of so-called carrier aggregation (CA) where multiple component carriers are aggregated and jointly used for transmission to/from a single mobile terminal.

Up to five component carriers, possibly each of different bandwidth, can be aggregated, allowing for transmission bandwidths up to 100 MHz.

A carrier-aggregation capable terminal can exploit the total aggregated bandwidth enabling higher data rates. In the general case, different numbers of component carriers can be aggregated for the downlink and uplink.

With respect to the frequency location of the different component carriers, three different cases can be identified:

* intra-band aggregation with contiguous carriers (e.g., aggregation of #2 and #3 in Fig. 2),
* inter-band aggregation (#1 and #4),
* intra-band aggregation with noncontiguous carriers (#1 and #2).

The possibility to aggregate non-adjacent component carriers enables exploitation of fragmented spectrum; operators with a fragmented spectrum can provide high-data-rate services based on the availability of wide overall bandwidth even though they do not possess a single wideband spectrum allocation.

Thus, although spectrum aggregation is supported by the basic specifications, the actual implementation will be strongly constrained, including specification of only a limited number of aggregation scenarios and aggregation over dispersed spectrum only being supported by the most advanced terminals.

**ENHANCED MULTI-ANTENNA SUPPORT**

This includes downlink transmit diversity based on space-frequency block coding (SFBC) for the case of two transmit antennas and SFBC in combination with frequency shift time diversity (FSTD) for four transmit antennas. In addition, downlink codebook-based precoding, including the possibility for multilayer transmission (spatial multiplexing) with up to four layers, is supported in LTE Release 8. This includes the possibility for rank-adaptation down to single layer transmission, leading to codebook-based beamforming, as well as a basic form of multiuser MIMO where different layers in the same time-frequency resource can be assigned to different terminals.

In Release 10, downlink spatial multiplexing is expanded to support up to eight transmission layers together with an enhanced reference signal structure.

Furthermore, feedback of channel-state information (CSI) is based on a separate set of reference signals broadcasted in the cell, known as CSI reference signals. CSI reference signals are relatively sparse in frequency (every 12th subcarrier, corresponding to 180 kHz) but regularly transmitted from all antennas at the base station.

**IMPROVED SUPPORT FOR HETEROGENEOUS DEPLOYMENTS**

As the possibilities to improve the link performance or increase the transmission power are limited, supporting very high end-user data rates requires a denser infrastructure.

Not only does a densified network have the possibility to increase the data rates experienced, it can also increase the overall capacity as the number of sites increase. A straightforward densification of an existing macro network is one possibility, but in scenarios where the users are highly clustered, a potentially attractive approach is to complement a macro cell providing basic coverage with multiple low output- power Pico cells where needed. The result of such a strategy is a *heterogeneous deployment* with two or more cell layers.

نظرًا لأن إمكانيات تحسين أداء الارتباط أو زيادة طاقة الإرسال محدودة، فإن دعم معدلات بيانات المستخدم النهائي العالية جدًا يتطلب بنية تحتية أكثر كثافة.

ليس فقط أن الشبكة المكثفة لديها إمكانية زيادة معدلات البيانات التي تمت تجربتها، بل يمكنها أيضًا زيادة السعة الإجمالية مع زيادة عدد المواقع. هناك احتمال واحد للتكثيف المباشر لشبكة ماكرو موجودة، ولكن في السيناريوهات التي يتجمع فيها المستخدمون بشكل كبير، يكون النهج الجذاب هو تكملة خلية ماكرو توفر تغطية أساسية مع خلايا بيكو متعددة الطاقة منخفضة الإخراج عند الحاجة. نتيجة هذه الاستراتيجية هي نشر غير متجانس مع طبقتين من الخلايا أو أكثر.

It is important to point out that this is a deployment strategy, not a technology component, and as such is possible already in LTE Release 8/9.

In a heterogeneous deployment, cell association (i.e., to which cell a terminal should be connected) plays an important role.

From an uplink data rate perspective, it is fundamentally beneficial to connect to the cell with the lowest path loss as this results in a higher data rate at a given transmit power, instead of the traditional approach of connecting to the cell with the strongest received downlink.

The best cell for downlink association depends on the load; at low load connecting to the cell with the strongest received downlink offers the highest data rates, while at high loads connecting to the low-power node may be preferable as it provides for downlink resource reuse between the cells served by the low-power nodes.

Cell association strategies in a heterogeneous deployment are therefore nontrivial where the overall network performance must be taken into account. Nevertheless, any cell association strategy not solely based on maximizing the received downlink signal quality can lead to a new interference situation in the network as, in essence, the uplink coverage area can be larger than the downlink coverage area, implying that there is a region around the low-power node (lighter ring in Fig. 3) where downlink transmission from the low-power node to a terminal is subject to strong interference from the macrocell.

*intercell interference coordination* (ICIC) mechanism present in LTE. With ICIC, different cells can exchange information about which frequencies they intend to schedule transmissions on in the near future, thereby reducing or completely avoiding intercell interference.

This can be used to more or less dynamically coordinate the resource usage between the cell layers and avoid overlapping resource usage.

LTE Release 10 provides enhancements to separate the control signaling for the different cell layers in either the frequency or time domain.

* Frequency domain schemes use carrier aggregation to separate control signaling for the different cell layers.

At least one component carrier in each cell layer is protected from interference from other cell layers by not transmitting control signaling on the component carrier in question in the other cell layers.

In essence, this creates frequency reuse for the control signaling while still allowing terminals to dynamically utilize the full bandwidth (and thereby supporting the highest data rates) for the data part.

* Time domain schemes use a single component carrier f in all the cell layers and separate the control signaling in the different cell layers in the time domain, as seen in Fig. 3.

To provide for accurate CSI feedback, Release 10 provides the possibility to configure on which subframes the terminal should base its channel-quality estimates as the interference experienced by a terminal connected to a low-power node may vary drastically depending on the macrocell activity.

The term closed subscriber groups (CSGs) is commonly used to refer to cases when access to such a low-power base station is limited to a small set of terminals (e.g., a family living in a house where the home base station is located). CSG results in additional interference scenarios.

Therefore, if closed subscriber groups are supported, it is preferable to use a separate carrier for the CSG cells to maintain the overall performance of the radio access network.

**RELAYING** البث على مراحل

LTE Release 10 also extends the LTE radio access technology with support for relaying functionality (Fig. 4). With relaying, the mobile terminal communicates with the network via a relay node that is wirelessly connected to a donor cell using the LTE radio interface technology. The donor cell may, in addition to one or several relays, also directly serve terminals of its own. The donor-relay link may operate on the same frequency as the relay terminal link (*inband relaying*) or on a different frequency (*outband relaying*).

يوسع الإصدار 10 من LTE أيضًا تقنية الوصول إلى الراديو بتقنية LTE مع دعم وظائف البث على مراحل (الشكل 4). مع البث على مراحل ، تتواصل الوحدة الطرفية المتنقلة مع الشبكة عبر عقدة ترحيل متصلة لاسلكيًا بخلية مانحة باستخدام تقنية واجهة راديو LTE. يمكن للخلية المانحة ، بالإضافة إلى واحد أو عدة مرحلات ، أن تخدم محطات مباشرة خاصة بها. قد يعمل رابط البث على مراحل المتبرع على نفس التردد مثل وصلة طراف البث على مراحل (مرحل داخل النطاق) أو على تردد مختلف (مرحل خارج النطاق).

This has the important advantage of simplifying the terminal implementation and making the relay node backward compatible.

In essence, the relay is a low-power base station wirelessly connected to the remaining part of the network.

One of the attractive features of a relay is the LTE-based wireless backhaul as this could provide a simple way of improving coverage, e.g., in indoor environments by simply placing relays at the problematic locations.

In Release 10 a gap in the relay-to-terminal transmissions to allow for reception of donor-to-relay transmissions is created using MBSFN *subframes Multicast-broadcast single- frequency network (MBSFN) subframes*, present already in Release 8, were originally intended for broadcast support but has later been seen as a generic tool (e.g., to blank parts of a subframe for relaying support).

In an MBSFN subframe the first one or two OFDM symbols in a subframe are transmitted as usual carrying cell-specific reference signals and downlink control signaling, while the rest of an MBSFN subframe is not used and can therefore be used for the donor-to relay communication.

Similar to the downlink gaps obtained through the use of MBSFN subframes, there is a need to create gaps in the terminal-to-relay transmission in order for the relay to transmit to the donor. This is handled by not scheduling terminal-to-relay transmissions in some subframes.

This control channel type, of which multiple instances can be configured, carries downlink scheduling assignments and uplink scheduling grants in the same way as the normal control signaling.

**PERFORMANCE RESULTS**

From the table it is seen that already the first release of LTE, Release 8, is capable of meeting all of the requirements except the bandwidth and uplink spectral efficiency requirements. These two requirements are addressed in Release 10 through carrier aggregation and uplink spatial multiplexing, respectively.