NR: The New 5G Radio Access Technology

NR will enable new use cases, requiring further enhanced data rates, latency, coverage, capacity, and reliability. This needs to be accomplished with improved network energy performance and the ability to exploit spectrum in very high frequency bands.

Introduction

The Third Generation Partnership Project (3GPP) process NewRadio (NR).

Mobile broadband (MBB) will drive the need for higher system capacity, better coverage, and higher data rates.

Massive machine-type communication (mMTC) where key challenges are to enable very low device cost and energy consumption, provide extreme coverage, and handle very large numbers of devices.

Ultra-reliable low-latency communication (URLLC), providing data delivery with unprecedented reliability in combination with very low latency,

Standardization Phasing and Time Plan

The first specification will be limited to non-standalone NR operation, implying that NR deployments will rely on LTE for initial access and mobility.

The mMTC use case can be handled by, for example, the narrowband IoT (NB-IoT) technology developed by 3GPP.

NR: Some Key Features, Higher-Frequency Operation and Spectrum Flexibility

NR is a substantial expansion in terms of the range of spectrum in which the radio access technology can be deployed

NR will operation from below 1 GHz up to 52.6 GHz1 as well as operation in both licensed and unlicensed spectrum.

Operation at millimeter-wave (mmWave) frequencies offers the possibility for a very large amount of spectrum and very wide transmission bandwidths, enabling very high traffic capacity and very high data rates. However, higher frequencies are also associated with higher radio channel attenuation, limiting the network coverage.

A substantial coverage disadvantage remains, especially in non-line-ofsight and outdoor-to-indoor propagation conditions. Thus, operation in lower frequency bands will remain a critical component for wireless communication in the 5G era. Specifically, joint operation in lower (e.g., below 3 GHz) and higher (e.g., mmWave) spectrum can provide substantial benefits.

Higher frequency will use large spectrum and high frequency mean low coverage area and that mean low pressure on bandwidth and the network.

Ultra-Lean Design

المشكلة في شبكات الاتصالات هي كمية النقل بغض النظر عن حركة المستخدمين.

بالمستقبل ومع توسع الشبكة فالضغط على العقد الشبكة سيكون اقل.

The always-on transmissions have two negative impacts:

• They impose an upper limit on the achievable network energy performance.

• They cause interference to other cells, thereby reducing the achievable data rates.

الزبدة في السطر التاني

The ultra-lean design principle aims at minimizing the always-on transmissions, thereby enabling higher network energy performance and higher achievable data rates.

Forward Compatibility

basic design principles related to

NR forward compatibility:

• Maximizing the amount of time and frequency resources that can be flexibly utilized or that can be left blanked without causing backward compatibility issues in the future

• Minimizing transmission of always-on signals

• Confining signals and channels for physical layer functionalities within a configurable/ allocable time/frequency resource

Note that these design principles partly coincide with the aim of ultra-lean design as described above.

NR: Technology Overview, Transmission Scheme and Frame Structure

NR is based on orthogonal frequency division multiplex (OFDM)

NR supports a flexible numerology with subcarrier spacings ranging from 15 kHz up to 240 kHz with a proportional change in cyclic prefix duration.

A small subcarrier spacing has the benefit of providing a relatively long cyclic prefix in absolute time at a reasonable overhead, while higher subcarrier spacings are needed to handle, for example, the increased phase noise at higher carrier frequencies.

The NR frame structure is A 10 ms radio frame is divided into ten 1 ms subframes. A subframe is in turn divided into slots consisting of 14 OFDM symbols each, that is, the duration of a slot in milliseconds depends on the numerology. Thus, for the 15 kHz subcarrier spacing, an NR slot has the same structure as an LTE subframe, which is beneficial from a coexistence

perspective. Since a slot is defined as a fixed number of OFDM symbols, a higher subcarrier spacing leads to a shorter slot duration. In principle, this could be used to support lower-latency transmission, but as the cyclic prefix also shrinks when increasing the subcarrier spacing, it is not a feasible approach in all deployments. Therefore, NR supports a more efficient approach to low latency by allowing for transmission over a fraction of a slot, sometimes referred to as “mini-slot” transmission.

Such transmissions can also preempt an already ongoing slot-based transmission to another device, allowing for immediate transmission of data requiring very low latency.

NR does not include cell-specific reference signals but solely relies on user-specific demodulation reference signals for channel estimation.

By locating the reference signals and downlink control signaling carrying scheduling information at the beginning of the transmission and not using time-domain interleaving across OFDM symbols, a device can start processing the received data immediately without prior buffering, thereby minimizing the decoding delay.

Duplex Schemes

For lower frequency bands, allocations are often paired, implying frequency-division duplex (FDD). At higher

frequency bands, unpaired spectrum allocations are increasingly common, calling for time-division duplex (TDD).

LTE support TDD uplink-downlink allocation does not change over time.

NR supports dynamic TDD as a key technology component. In dynamic TDD, (parts of) a slot can be dynamically allocated to either uplink or downlink as part of the scheduler decision. This provide rapid traffic variations with a relatively small number of users per base station.

There is also a possibility to semi-statically configure the transmission direction of some of the slots, a feature that can allow for reduced device energy consumption as it is not necessary to monitor for downlink control channels in slots that are a priori known to be reserved for uplink usage.

Channel Coding

Channel coding for NR data transmission is based on low-density parity check (LDPC) codes.

For the smallest control payloads, Reed-Muller codes are used.

Scheduling, Data Transmission, and Control Channels

The basic way of controlling data transmission in NR is scheduling in a similar way as in LTE. Each device monitors a number of physical downlink control channels (PDCCHs),

The PDCCHs are transmitted in one or more control resource sets (CORESETs) each of length one to three OFDM symbol(s).

Given the very high data rates supported by NR, the transport block size can become very large. Retransmitting the whole transport block could in this case become inefficient.

NR therefore supports retransmissions at a finer granularity, known as code-block group (CBG). An urgent transmission

to a second device may use only one or a few OFDM symbols and therefore cause high interference to the first device in some OFDM symbols only. In this case it may be sufficient to retransmit the interfered CBGs only and not the

whole data block.

Beamforming and Multi-Antenna Transmission

NR is Support for a massiveMIMO.

Channel state information (CSI) for operation of massive multi-antenna schemes can be obtained by feedback of CSI reports based on transmission of CSI reference signals in the downlink, either per antenna element or per beam, as well as using uplink measurements exploiting channel reciprocity.

NR support analog beamforming in addition to digital precoding/ beamforming.

Analog beamforming results in the constraint that a receive or transmit beam can only be formed in one direction at a given time instant and requires beam-sweeping where the same signal is repeated in multiple OFDM symbols but in different transmit beams.

With beam-sweeping possibility, it is ensured that any signal can be transmitted with a high gain, narrow beamformed transmission to reach the entire intended coverage area.

Beam management procedures and signaling are specified, such as indication to the device to assist selection of a receive beam (in the case of analog receive beamforming) to be used for data and control reception, respectively.

NR, extended support for such multi-user spatial multiplexing is introduced, either by using high-resolution CSI feedback with a linear combination of DFT vectors, or uplink sounding reference signal improvements targeting the utilization of channel reciprocity.

The device can receive multiple PDCCH and multiple physical data shared channels (PDSCHs) per slot to enable simultaneous data transmission from multiple transmission points to the same user.

Phase tracking reference signal is introduced in NR since the increased phase noise power at high carrier frequency bands otherwise will degrade demodulation performance for larger modulation constellations, such as 64-quadrature amplitude modulation (QAM).

Initial Access

• There is a pair of downlink signals, the primary synchronization signal (PSS) and secondary synchronization signal (SSS), that is used by user equipment (UE) to find, synchronize to, and identify a network

• There is a downlink physical broadcast channel (PBCH) transmitted together with the PSS/SSS.

• There is a four-stage random access procedure, commencing with the uplink transmission of a random access preamble.

Interworking and LTE Coexistence

As it is difficult to provide full coverage at higher frequencies, interworking with systems operating at lower frequencies is important.

In particular, a coverage imbalance between uplink and downlink is a common scenario, especially if they are in different frequency bands.

Through interworking, a high-frequency NR system can complement a low-frequency system. The lower-frequency system can be either NR or LTE, and NR supports interworking with either of these.

LTE/NR spectrum coexistence, that is, the possibility for an operator to deploy NR in the same spectrum as an already existing LTE deployment, has therefore been identified as a way to enable early NR deployment in lower frequency spectrum without reducing the amount of spectrum available to LTE.

NR: Performance