Understanding PUSCH Frequency Hopping in LTE

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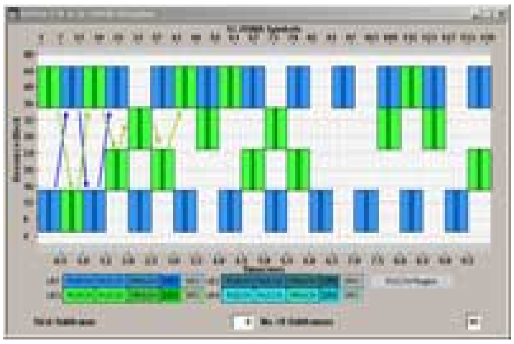
UMTS Long Term Evolution, short LTE, is the technology of choice for the majority of network operators worldwide, providing mobile broadband data and high-speed internet access to their subscriber base. Due to the high commitment LTE is understood as the innovation platform for the wireless industry for the next decade. That's the reason why I link the abbreviation LTE to the term LONG TERM EMPLOYMENT. The technology itself is high complex, utilizing advanced procedures on top of what we know from existing standards such as WCDMA or HSPA. This blog picks interesting aspects of LTE and takes a closer look while providing some explanations around it. A basic understanding of the concepts used for LTE and standardized by the 3rd Generation Partnership Project (3GPP) is assumed while reading.

Understanding Frequency Hopping in the LTE Uplink

The Physical Uplink Shared Channel (PUSCH) is shared by all devices (user equipment, UE) in a radio cell to transmit their data to the network. The scheduling for all UEs is under control of the LTE base station (enhanced Node B, eNB). The eNB uses the uplink scheduling grant (DCI format 0) to inform the UE about resource block (RB) assignment, modulation and coding scheme to be used. In LTE as of 3GPP Release 8 only contiguous RB allocation is allowed for the uplink, utilizing resource allocation type 2. Applying a distributed allocation would minimize the gain of reducing the peak-to-average power ratio (PAPR) achieved while introducing Single Carrier FDMA (SC-FDMA) as the uplink transmission scheme of choice.

The standard allows two modes for frequency hopping, enabled by higher layer signaling, from one to the other time slot (intra-subframe) and from one to the other subframes (inter-subframe), or just between subframes. Using hopping enables the UE to exploit the frequency diversity of the wideband channel used in LTE while keeping the required contiguous allocation. Hopping is activated by just setting a flag in the DCI format 0, however the applied principles are quite complex. An UE will first determine the allocated resource blocks after applying all the frequency hopping rules. Then, the data is being mapped onto these resources, first in subcarrier order, then in symbol order.

In terms of hopping, two essential bits of information are provided by the network, beside the hopping mode. First, the number of subbands the available bandwidth is split into, which can be 1, 2, 3 or 4. Second, a frequency offset as a number of RB. Let's take an example with a 10 MHz signal, equals 50 RB. In case a hopping offset of 10 RB is defined by the network, defining also the maximum number of subbands, there are 10 RB per subband, according to the rules defined in the related 3GPP specification. This number changes, when number of subbands and/or hopping offset is changed. The effect is that the number of RB that can be allocated to a device, for which one hopping is enabled, are limited. In our example such a device can only transmit on a maximum of 10 RB.



[1]

Furthermore two types of uplink hopping are defined in LTE: Type1 and Type2. How does the UE know which type to follow? Well, this is signaled in the uplink scheduling grant as part of the Resource Indication Value (RIV), that informs the device which RB to use and which start offset to apply. But first we need to understand, that there is 1 or 2 so called hopping bits, dependent on the bandwidth. For less than 50 RB its only one bit, for more and so in our example two bits are used.

For the bit combinations 00bin, 01bin and 10bin its Type1 PUSCH hopping, only for 11bin its Type 2 PUSCH hopping. Now the difference between both types is actually how the hopping is performed. Applying Type 1 results in a certain offset between the two allocations where the UE jumps to from one slot to the other and/or subframe to subframe. This offset is dependent on number of RB, signaled hopping offset and start of the actual allocation for this device.

Type 2 follows a specific hopping pattern that is defined by subband size, hopping offset, and a hopping and mirroring function. The hopping and mirroring function are both dependent on the cells identity, which makes the frequency hopping specific and unique to each radio cell in the network. Figure 1 shows an example where an UE applies Type 1 and another one does Type 2, based on the above mentioned example. Both devices are commanded to use same the resource allocation. It can be seen, that Type 1 hopping jumps always between two allocations. It can be understood as constant, where Type2 seems to have a random character.

Be sure to check out next month's blog on "Understanding Downlink Power Allocation in LTE."