UNDERSTANDING THE LTE DOWNLINK : PART 3

I've been explaining the LTE downlink using a "toy version" based on a table. Does LTE really use a table? Yes it does, but in proper LTE parlance it's called a "resource grid", not a table. And a table entry is referred to as a "resource element" (RE for short). How does a real resource grid differ from my toy table? There are 4 major differences:

1. Lots more rows and columns
2. More structure
3. Longer transmission time
4. Public information

Let's take those items one at a time.

Rows and Columns

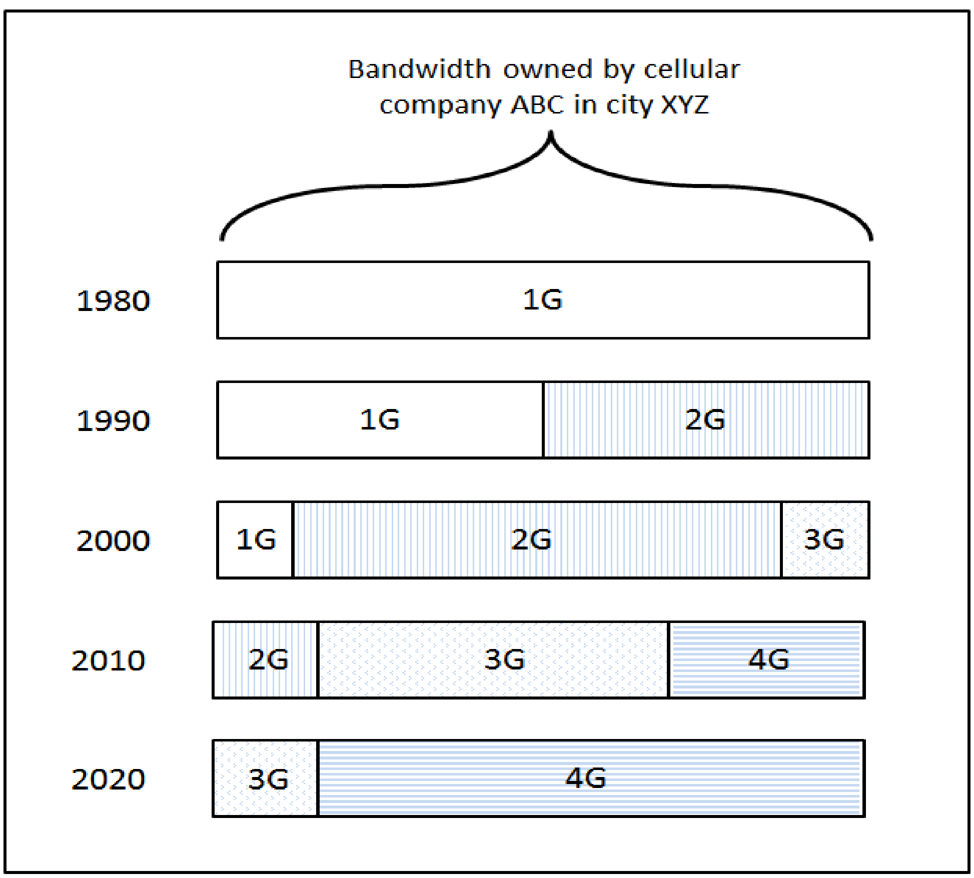
My toy table had 6 rows and 4 columns. A real LTE resource grid will have between 73 and 1201 rows, and either 120 or 140 columns.

The decision as to how many columns to use involves a tradeoff between data throughput and robustness (which we've seen before and which is a constant theme in wireless communications). Using 140 columns means potentially 16% greater data capacity. But since the entire table has to be transmitted in a fixed amount of time, it means there is less time allocated for each column – 12 microseconds as a matter of fact. Twelve extra microseconds means that more "slop" is available in the received signal at the cell phone, increasing the chances that it will be able to properly decode the signal. The choice is not a dynamic one. It's made when the cell tower is configured and is based on the things like how large the cell will be and what the environment is like. With a big cell there's more scope for bad things to happen to the signal on its way to the cell phone. Also, for example, in downtown Manhattan the signal has a much harder time "finding" the cell phone than it does in a wheat field in the Midwest. This doesn't mean that the number of columns will never change. Cellular service providers are always tweaking their networks. But the changes happen on a timescale of months rather than milliseconds.

How about the number of rows? Whereas columns correspond to time in LTE, rows correspond to frequency – rows at the bottom of the grid correspond to lower frequency than those at the top of the grid, and the total number of rows corresponds to a certain amount of bandwidth. So the factor that determines the number of rows is how much bandwidth is available. Only certain values are allowed. The following table lists the allowed bandwidth sizes and the corresponding number of rows.

Available Bandwidth (MHz)	Number of Rows in Resource Grid
1.4	73
3	181
5	301
10	601
15	901
20	1201

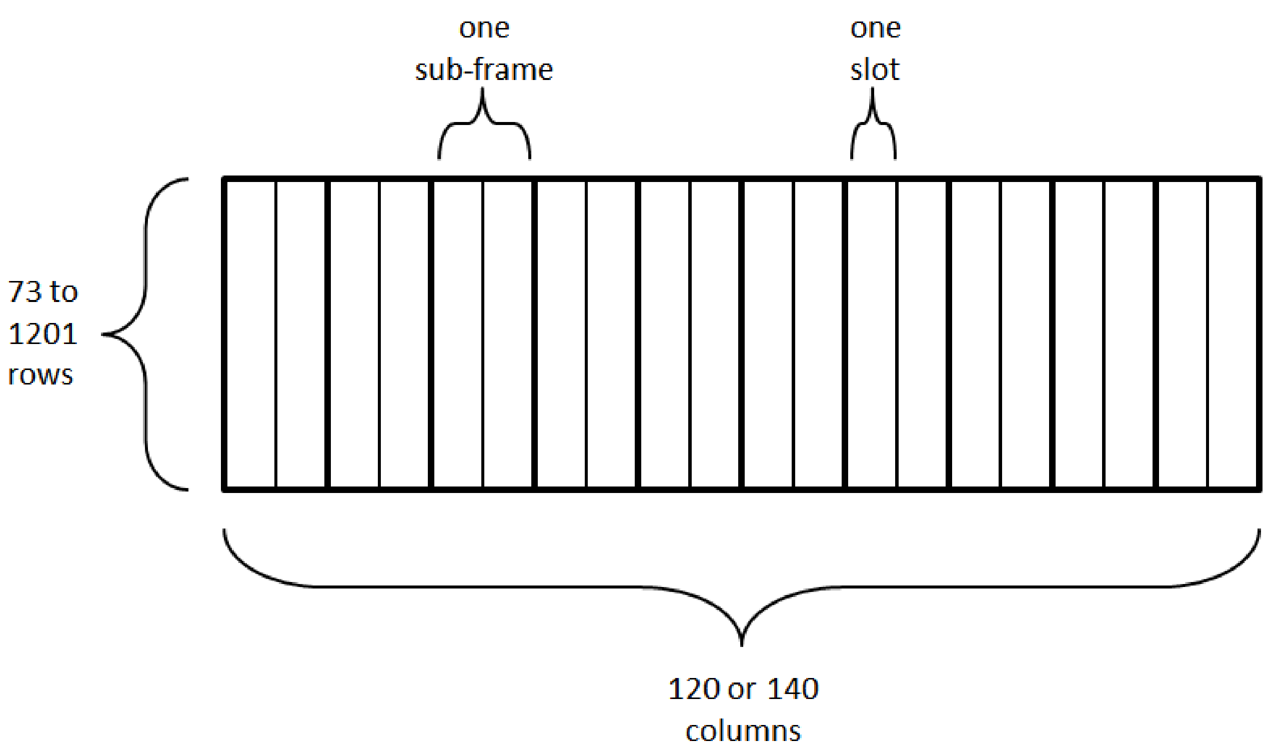
The relationship between number of rows and data capacity is simple – more rows equals more capacity. So why not always use 1201 rows? Think back to that day last year when you and everyone else in the world had to throw away your 3G phone and go out and buy a brand new 4G phone. Remember that day? Of course not, because it never happened. A given service provider in a given location only has so much bandwidth, and he has to use that bandwidth to support not only LTE phones but also 3G phones, and even 2G phones! One of the burdens in the business of cellular services is readjusting bandwidth allocations as the population of cell phone types changes. The following timeline illustrates the idea:



As time goes by the bandwidth allocation changes, with less bandwidth being given to older technologies. Hopefully the change in bandwidth mirrors the change in actual cell phone numbers, as users switch from older phones to newer ones.

More Structure

Unlike my toy table the resource grid has a defined substructure. The entire table is referred to as a “frame”. The frame is divided vertically into 10 “sub-frames”, and each sub-frame is again divided vertically into 2 “slots”. When I say the table is divided vertically I mean that each sub-frame or slot encompasses all the rows, but only some of the columns. Each slot will have either 6 or 7 columns (which gets reflected in the total table having either 120 or 140 columns). The picture looks like this:

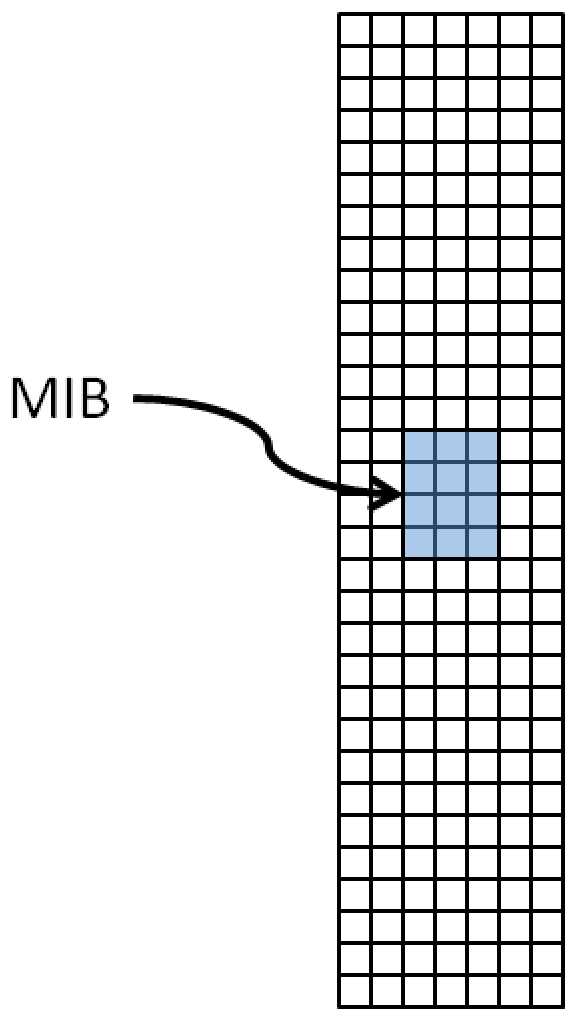


Resource Groups

In my 4G toy table I did user RE allocation on an individual table entry basis. Thus, for example, user Bob might be assigned 1 resource element, or 5, or 17. In real life the overhead of doing this would be prohibitive. For a real resource grid the resource elements are gathered together in groups of either 72 (6 * 12) or 84 (7 * 12), and allocation is done on a group basis. Thus Bob might be assigned 72 RE’s (IE one resource group), or 144 (2 resource groups), or 720 (10 resource groups) – but never 1 or 35 or 111.

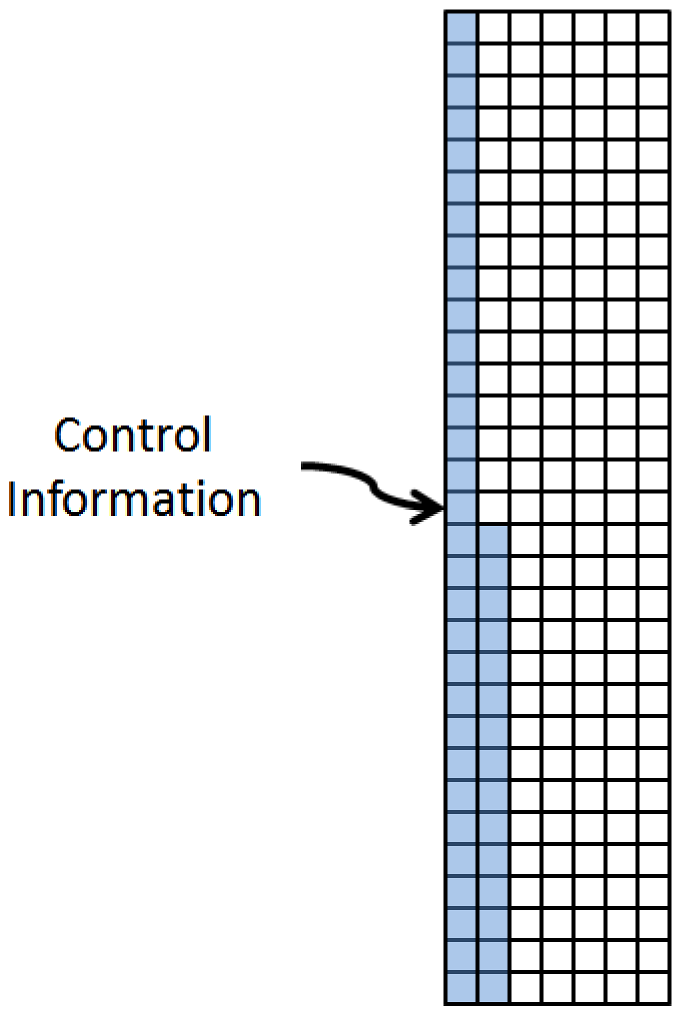
Table Marker

My toy table placed the marker signal – the thing that allows the cell phone to sync up with the cell tower, in the upper left corner of the table. In real life the marker is placed vertically in the center of the table, it is several columns wide, and it is duplicated in two slots (slot 0 and slot 5). It is also officially called the Master Information Block (MIB). It has that name because the marker actually has embedded in it some basic information about how the cell tower is operating. Here's a more realistic picture of one slot, showing how the MIB is positioned:



Control Information

In my toy table I placed the control information as a fixed number of elements in the lower left corner. In reality, the control information is placed in the leftmost columns of the grid. The size of the control info region can vary – it depends on how complicated the division of the table is – and it does not need to use a discrete number of columns. In the example below, the control information is taking up one and a half columns:



Transmission Time

In my toy table I talked about processing a table in half a millisecond. In real LTE, half a millisecond is the time to process a single slot. An entire resource grid corresponds to 10 milliseconds (IE to 20 slots). Exactly how the generation and processing of a table is done will be vendor specific, but it's probably more realistic to think in terms of 10 millisecond chunks, rather than 0.5 millisecond chunks.

Public Information

So far I've identified the following types of information broadcast by the cell tower:

1. "Marker Signals" (IE the "MIB")
2. Reference Signals
3. Control Information
4. User Data

The tower also broadcasts the following additional information, that is "publicly available" to all the cell phones interacting with the cell tower:

5. Pages
6. Cell Tower Specifics
7. Miscellaneous Information of General Interest

Note that this data is sent the same way that user data is. In other words, when the cell tower is figuring out how to allocate resource groups amongst the various users (Ann, Bob, Carol, etc), it must also decide how much space to allocate for pages, cell tower specifics, and miscellaneous information. The big difference is that individual user data is encrypted, while this data is not. Since it is not encrypted, all cell phones have access to it. Let's do a brief description of each of these in turn.

Pages

Not only can you call people from your cell phone, but other people can call you on your cell phone. The action of the cell tower notifying your cell phone that someone is trying to call you is termed a "page". The basic idea is that periodically the cell tower broadcasts a block of data containing information about any outstanding requests to connect to cell phones (the cell phones using that particular cell tower, not all the cell phones in the world!). All cell phones pay attention to those broadcasts, and when a phone sees a request directed to it, it notifies the cell tower that it is willing to establish a call.

Cell Tower Specifics

LTE is highly configurable. In order to properly interact with a cell tower a cell phone needs detailed information about exactly how the cell tower is set up. So cell towers periodically broadcast information about their configuration. All cell phones pay attention these broadcasts when they are first trying to establish communication with the cell tower, and they continue to monitor them to pick up any changes that may occur.

Miscellaneous Information

LTE also has the ability to broadcast certain types of information of general interest. For example, LTE includes a way to broadcast tsunami warnings to all 4G cell phones. So someday, if you're on the beach and your cell phone starts beeping like crazy and flashing "TSUNAMI" on the screen, you'd better get yourself to higher ground, ASAP!