PRIMER

Much has been done to accurately measure the time error associated with network equipment, however, measuring the time error of an LTE basestation with no 1pps output is a challenging problem. One option is to make a measurement of the downlink radio signal.

This primer describes how to make such an over-the-air "time error" measurement by decoding and examining the so-called synchronisation signals and comparing them to an external time reference.

Making Over-the-Air SYNC MEASUREMENTS

Introduction to LTE Downlink Radio Frame Timing

The LTE radio downlink is an OFDMA (Orthogonal Frequency Division Multiple Access) signal – which means that it uses both Frequency and Time Division multiplexing to share resources between users. Full details can be found in the 3GPP specifications or in other publications.

In the time domain, the transmission consists of 10ms frames. Each frame is divided into 10 subframes. Each subframe is further divided into 2 timeslots, each of which contains 6, or more usually 7 symbols. Each symbol also contains a cyclic prefix, (to cope with multipath effects) resulting in a useful symbol length of 66.7us.

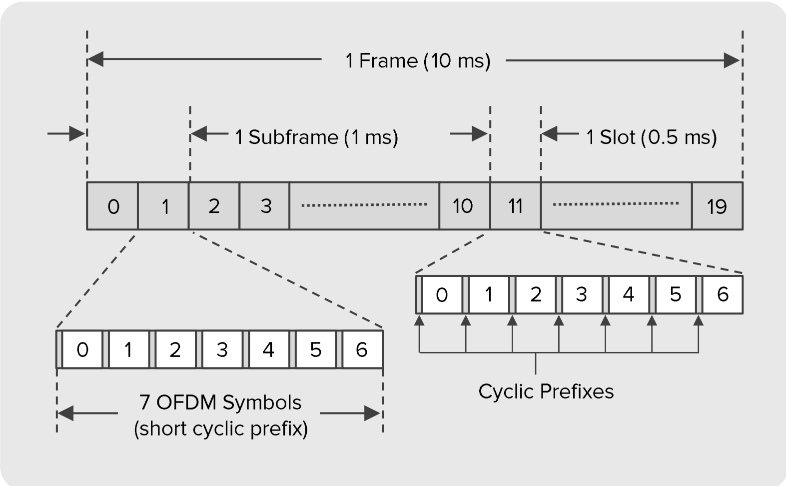

Figure 1. LTE Frame Structure

There are also two duplex schemes for managing uplink and downlink transmissions. These are Frequency Division Duplex (FDD) and Time Division Duplex (TDD). In FDD the uplink and downlink are on different frequencies but are both continuous. In TDD they are on the same frequency and switch between transmit and receive according to a specific schedule.

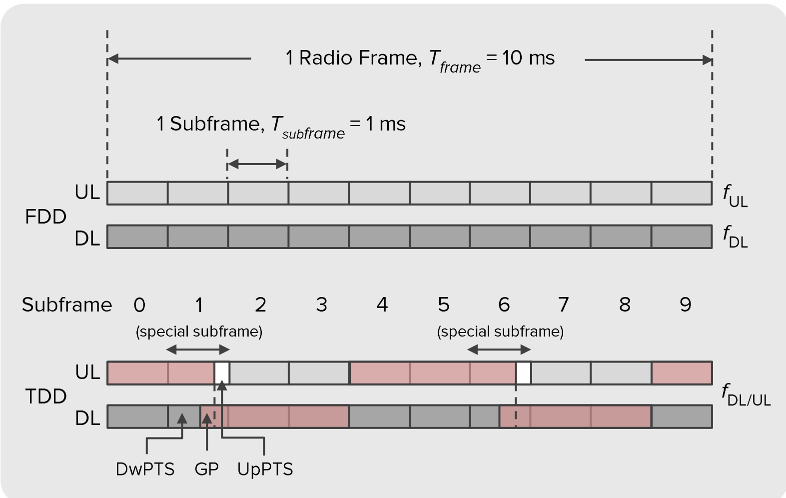

Figure 2. Comparison of FDD and TDD Frame Structures

FDD has typically only required that basestations within the network be syntonised – or frequency aligned, whereas TDD requires that they be phase aligned within 3 us. This is to avoid interference issues. Some features now available within FDD such as eICIC (Enhanced Inter-Cell Interference Coordination) and CoMP (Coordinated multi-point) also require phase alignment. The standards do not describe how this alignment should be achieved. One method – and the one we assume for our measurement – is to start transmission of the first frame from each basestation at the top of second. This means that the start of every hundredth frame transmitted will occur at top of second.

Note that it is not possible just by listening to the radio signal to determine where every hundredth frame will occur. The system frame number is modulo 1024, so some assumptions have to be made.

The frames transmitted on the downlink contain a mixture of user data, control data and specific signals used for synchronisation and measurements. There are two such synchronisation signals that are each transmitted twice within a frame. These are the Primary and Secondary Synchronisation Signals (PSS and SSS). User Equipment (UEs) synchronise to a basestation (Enode-B) by detecting these signals and using them to determine their own timing relative to the base station. This ensures that they receive and transmit at the correct times.

These signals always appear at the same points within the radio frame – although the relative positioning in time varies between FDD and TDD. These signals also encode the physical cell ID – but they do not encode any information about the actual time – they are simply markers. The synchronisation signals each occupy a single symbol in time, spread across the central 72 subcarriers.

Measuring Time Error Over the Air

An absolute time error measurement can be made by tuning the receiver to the correct frequency, down-converting, digitizing and demodulating the radio signal and finding the position of the PSS within the radio frame. The absolute time position of the PSS can be determined using an external reference such as GPS. This can then be used to determine the absolute start time of the frame. By assuming that transmission is initiated at top of second as described above and that any error is within a maximum of 10ms, and allowing for time of flight from the antenna and any other delays, it is possible to determine the absolute time error of the basestation. Of course, if transmission starts at a known offset from top of second then it is possible to compensate appropriately.

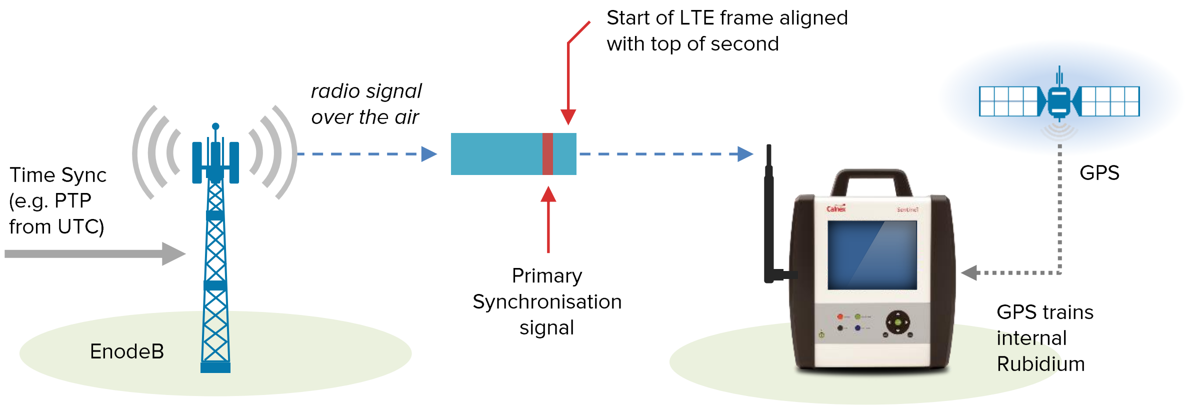

Figure 3. Making a Time Error measurement by using the PSS to determine the start of Frame Time

In practice the technique requires a little more work than this due to the way that the LTE signal is specified. The PSS transmitted in each half of the frame (1 of 3 possible sequences) is the same – but the SSS (1 of 168 possible sequences) differs slightly – allowing determination of which half of the frame has been detected. The relative positioning of the SSS versus the PSS determines whether FDD or TDD is in use.

The accuracy and resolution of the measurement are partly determined by the rate at which the radio signal is sampled, (the higher the rate the better the resolution). Typically, the sample rate for LTE is 30.72 MHz, resulting in a sample time or resolution of approximately 32.5 ns. A higher sampling rate can be used to achieve higher resolution.

To find the absolute time of signal reception it is necessary to timestamp the RF samples as they are gathered. These timestamps are stored along with the samples. The PSS and SSS and their positions are determined by correlating the received samples with ideal signals. The timestamps of the correlated samples can then be used to provide an absolute measurement.

To achieve the best accuracy of the measurement it is necessary to accurately measure the distance from the measuring receiver to the basestation and to characterise the delays within the receiver.

Other Applications

As well as measuring the absolute time error of an individual basestation, this technique can be extended to make other useful measurements.

Relative Timing Error

As well as making measurements of an individual base station it is possible to measure two basestations in quick succession – and thus determining the relative time error between them. As well as for TDD, this is of particular interest in the case of FDD cells where eICIC is in use – since this requires coordination of downlink power control between cells.

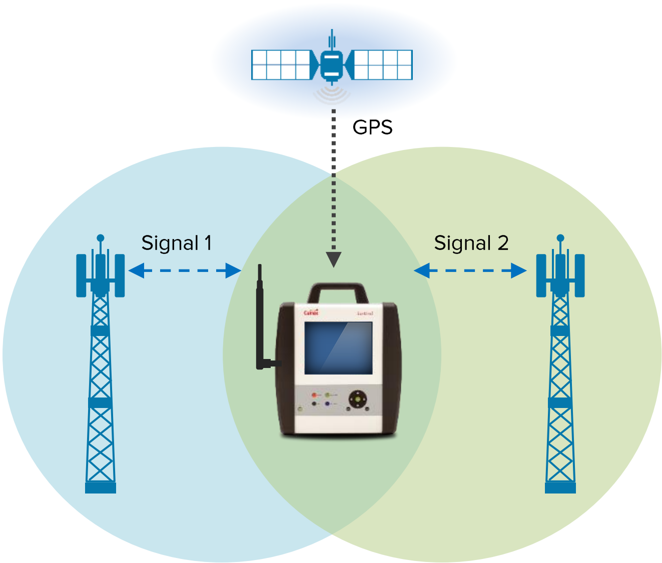

Figure 4. Test set compares timing of Signal 1 and Signal 2 vs GPS (external reference)

For this measurement to work it is necessary to be able to receive the signal from both basestations at a single location and to differentiate between them. This can be challenging as LTE is a single frequency network, and the PSS and SSS signals are not designed to be interference resistant. (Note – the specific signals will be encoded differently for different base stations.) In practice it will be necessary to be near the inter-cell boundary.

Observed Time Difference of Arrival (OTDOA)

A scheme is defined within LTE for determining position by comparing the relative arrival time of specific signals from 3 (or more) basestations and triangulating. This is designed for use by emergency services for example, in order to locate an incident. The full application requires the use of a defined protocol to determine when the particular signals are transmitted, and in the case of a UE, to command them to make measurements and return the measurements to the network.

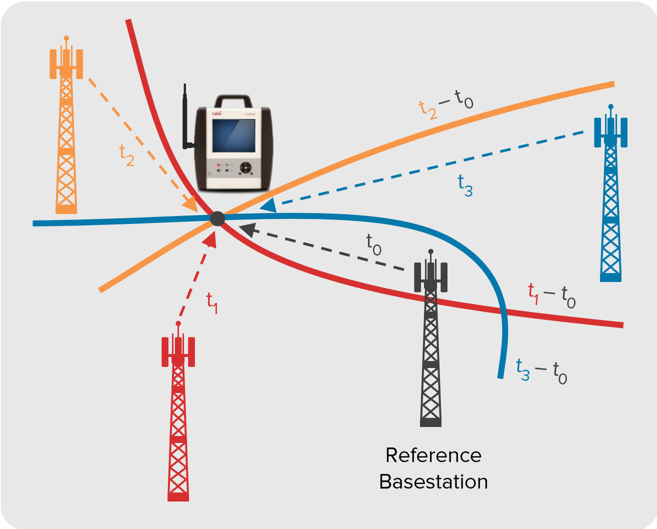

Figure 5. Observed time difference of arrival

For test equipment it is only necessary to know when and where within the downlink structure for each basestation, to listen for the particular signals. There is no requirement to return the measurements to the network.

The signals are of a similar form to those used for the SSS. As for the relative timing case above it is necessary to be in a location where signals from all three stations can be received. Because the transmission of these signals is coordinated between the basestations this is potentially easier than receiving and measuring different PSS/SSS combinations.

By making measurements of these signals and comparing them to each other, using the external reference, it is possible to determine the accuracy of the positioning scheme.

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