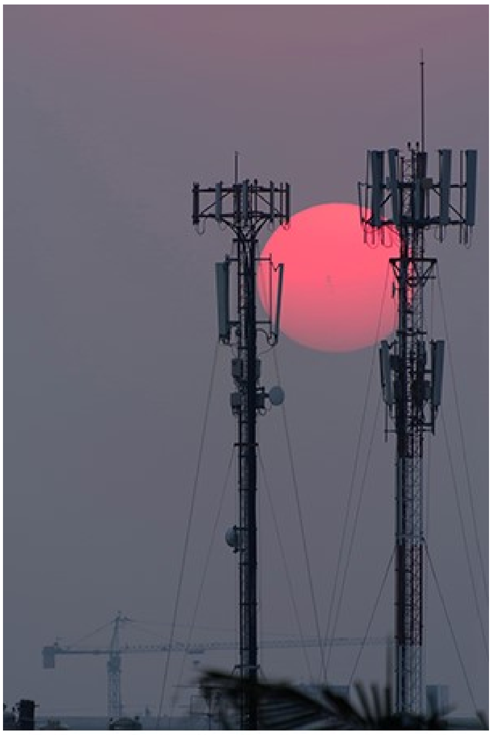

WHY DO CELLULAR BASESTATIONS NEED SYNCHRONIZATION?

Answered by an industry expert

ABSTRACT

This critical requirement in today's networks is explored by considering six key questions.

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Calnex Strategic Marketing Manager

What are the synchronization requirements of mobile basestations?

Mobile Technology	Frequency accuracy	Phase accuracy *(Frame alignment to adjacent cells)*	Time accuracy *(relative to overall system time)*
CDMAOne, CDMA2000	**±50 ppb**	*N/A*	**±3µs** (normal operation) **10µs** (in holdover)
GSM	**±50 ppb**	*N/A*	
WCDMA (UMTS)	**±50 ppb**	*N/A*	
TD-SCDMA	**±50 ppb**	**± 3µs**	*N/A*
LTE (FDD)	**±50 ppb**	*N/A*	
LTE (TDD)	**±50 ppb**	**±3µs** (< 3km cell radius) **±10µs** (> 3km cell radius)	*N/A*
LTE-A MBSFN	**±50 ppb**	**±1 to 5µs** *implementation dependent*	*N/A*
LTE-A CoMP (Network MIMO)	**±50 ppb**		
LTE-A eICIC (HetNet Coordination)	**±50 ppb**		
Small Cells	**±100 ppb**	*N/A* (FDD) **±3µs** (TDD) **±1 to 5µs** (eICIC)	*N/A*
Home Cells	**±250 ppb**	*N/A* (FDD) **±3µs** (TDD)	*N/A*

What do these terms mean?

Frequency accuracy:

The maximum difference between the carrier frequency of the basestation and the nominal value. This is typically expressed as a fraction of the nominal value, e.g. 'ppb" = 'parts per billion", or billionths of the nominal frequency.

Phase accuracy:

The maximum deviation in frame start times between cells with overlapping coverage areas.

Time accuracy (for CDMA and CDMA2000 technologies):

The maximum pilot time alignment error to CDMA system time.

Why do basestations require frequency synchronization?

1. Regulation and licensing of spectrum

Spectrum is an expensive commodity, licensed by governments to the mobile operators at high cost. Operators would be in breach of their license conditions if they were to transmit outside of their licensed spectrum band.

2. Interference with other basestations

Basestations could potentially cause interference to signals coming from nearby basestations if they transmit outside of their assigned bands.

3. Handoff for mobiles moving between cells

Mobile handsets synchronize to the basestation they are connected to. When they move to another basestation, they know the frequency of the basestation relative to their current connection. If one of those basestations was not at the correct frequency, they may not find the new basestation, and the call could be dropped.

4. Quality of service

Both of the above two issues are quality-of-service issues, leading to dis-enchanted customers. This makes it more likely that those customers will switch to an alternative operator providing better service.

Why do small cells and home cells have a more relaxed requirement?

Remember the Doppler Effect from your high school physics? This is the effect that causes a police siren to sound high pitched as it is coming towards you, and change to a much lower pitch as it passes you and moves away. The siren itself hasn't changed frequency, but as it travels towards you, the sound waves are compressed by the motion, causing them to sound higher-pitched. Then as the car moves past you the sound waves are stretched, causing them to sound lower in pitch.

The same thing happens with mobiles. As we drive around in our cars, or travel on trains, we may be moving away from one basestation and towards another. This causes a Doppler shift in the perceived frequency coming from the basestation. For example, travelling on the TGV at 320km/h directly towards a basestation would create a Doppler shift of about 300ppb. As you move past the basestation that changes quickly to a Doppler shift of -300ppb.

Since mobile handsets typically have an acceptance range of around 300ppb on the input frequency, any error in the basestation frequency would result in the handset being unable to connect to the basestation.

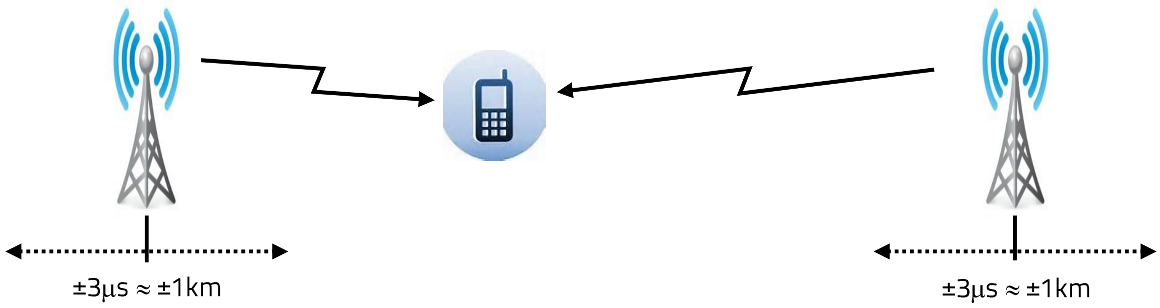
Users of small cells and home cells are not usually travelling at such high speeds, therefore the frequency requirements on the basestation can be relaxed relative to those of macrocells. For example, users of home cells are rarely travelling faster than walking pace, so the accuracy requirement is close to the acceptance limit of the mobile handsets. This also helps to keep the cost down, since these are typically consumer devices.

Why do basestations require time synchronization?

For the European 2G and 3G standards (GSM and UMTS), there is no requirement for tight time synchronization. These basestations only require accurate frequency synchronization from the network.

For the equivalent North American standards, CDMAOne and CDMA2000, there is a requirement for the basestations to be synchronized to within 3µs of CDMA system time, a centralized clock for the whole network. The primary reason for this is to facilitate 'soft handoff", the means to pass control of a handset from one basestation to the next.

Each basestation periodically transmits a pilot signal, which is a code that announces the basestation to handsets in the vicinity. The handset looks for these pilot signals, and expects to see pilot signals from different basestations arrive at roughly the same time. If a pilot signal from one basestation arrives before that from another, it is an indicator that one basestation is nearer than another.



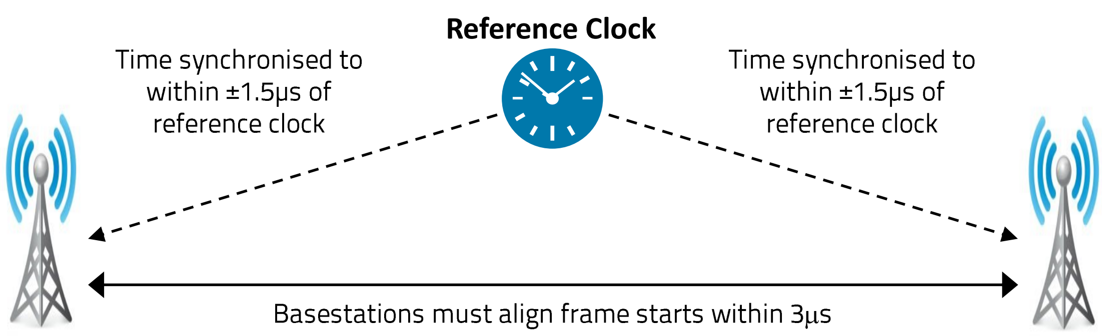
An error in the alignment of these pilot signals is perceived by the handset as a basestation being either nearer to or further away than it actually is. A 3µs time error is the equivalent of a 1km difference in distance.

Why do LTE (4G) basestations require time synchronization?

Most initial deployments of LTE have been FDD (Frequency Division Duplexing), where the upstream and downstream transmissions are carried on different frequencies. LTE FDD has no requirement for tight time synchronization.

Some deployments, particularly in China, have used TDD (Time Division Duplexing) technology, where the upstream and downstream transmissions are carried in different timeslots. This does require tight alignment between frames from different basestations to avoid contention and the potential impact on service quality.

The LTE TDD specification mandates the frame time alignment between overlapping basestations should be within 3µs. This is a phase accuracy specification between basestations. Normally this is achieved by ensuring that each basestation is aligned to within ±1.5µs of a central reference clock, which is therefore a time accuracy specification relative to the reference clock.



What about LTE Advanced?

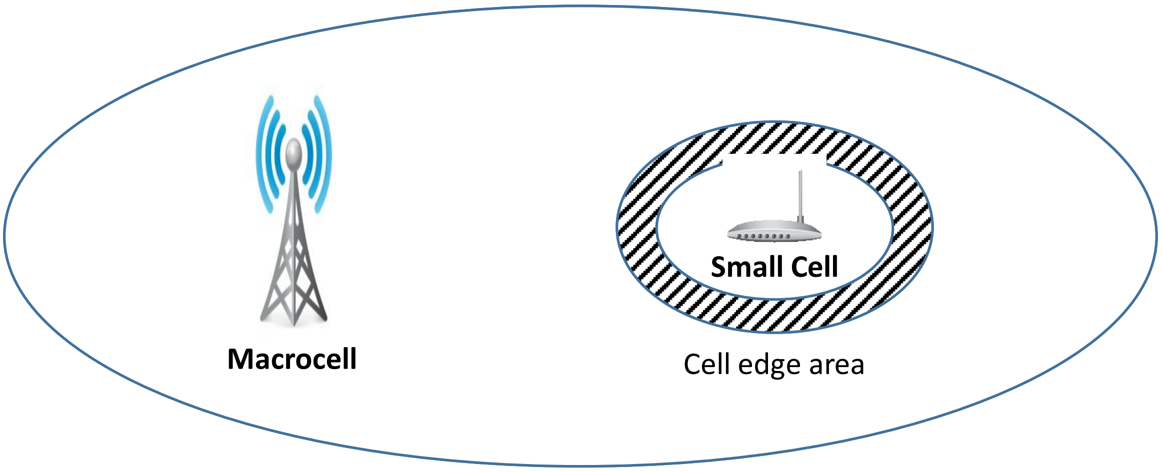
LTE Advanced is a collection of techniques that operators can deploy to improve data rates and quality of service. Each technique has its own requirements, some of which relate to time and phase synchronization.

Enhanced Inter-Cell Interference Co-ordination (eICIC)

Small cells are often deployed within congested macrocells to offload traffic from the macrocell. This is typically true in a dense urban environment, such as a busy street or shopping area. Users close to the small cell pick up that cell instead of the macrocell, while further away the macrocell dominates, so users pick up that instead.

The issues occur in the cell edge area at the boundary of the small cell coverage. In these edge areas, it may be difficult for the handset to pick up the small cell because of the interference from the macrocell.

The solution is a technique called 'Enhanced Inter-Cell Interference Co-ordination", or eICIC. At pre-determined intervals, the macrocell basestation transmits an 'almost blank sub-frame" (ABSF), which is a very low power signal, effectively turning the macrocell off for a short period. During the ABSF, the small cell transmits its identifier, allowing the handset to pick up the small cell and lock to it, increasing the effectiveness of the small cell.



The co-ordination of the almost blank sub-frames requires some level of phase synchronization between the macrocell and the small cell. There is no exact specification for this phase synchronization, since there is no point at which the technique stops working – it just degrades in efficiency to the point where it no longer achieves any performance gain.

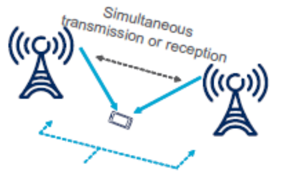
Therefore there is a tradeoff for the operator between the desired efficiency gains and the level of phase synchronization required. Most deployments aim for phase synchronization between cells of between 1 and 5μs.

Co-ordinated Multi Point Transmission and Reception (CoMP)

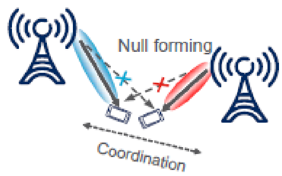
Co-ordinated Multi Point is a family of techniques that allow for multiple basestations to function together. This can achieve higher throughput and data transfer rates than by functioning independently.

There are four main CoMP techniques proposed:

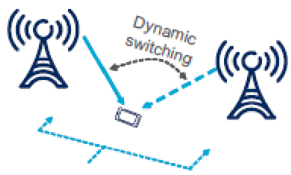
1. **Joint Transmission or Reception:**
   The use of two or more basestations to simultaneously transmit to or receive from the same handset.
2. **Co-ordinated Beamforming:**
   Interference reduction technique to create a null at the handset, cancelling the transmission from a neighbouring basestation.
3. **Dynamic Point Selection:**
   Time domain switching between basestations, allowing more efficient use of resources.
4. **Dynamic Point Blanking:**
   Time domain scheduling of transmissions to avoid interference between basestations transmitting to different handsets.



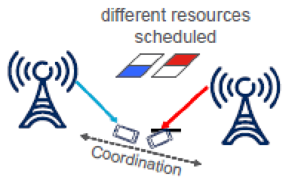
Joint Transmission or Reception



Coordinated Beamforming



Dynamic Point Selection



Dynamic Point Blanking

All of these techniques require tight synchronization between basestations, with some requiring much tighter synchronization than others. As for eICIC, there is no exact limit defined for each technique, they degrade in efficiency as the synchronization is relaxed. Most deployments aim for phase synchronization between cells of between 1 and 5μs.

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