TSG-RAN Working Group1 meeting #3 TSGR1#3(99)165

Nynäshamn, 22. – 26. March 1999

Agenda Item:

Source: SIEMENS

Title: **TDD Synchronisation**

Document for: Discussion and approval

1. Introduction

In order to minimise the interference in a TDD – system frame synchronisation is necessary. Therefore the Node B in a network have to be synchronised on the air-interface to each other. There are 3 possibilities achieve this :

- Synchronisation via the air-interface
- Synchronisation via I_{ub} – interface
- Synchronisation to external equipment

In case of synchronisation via the air-interface the following concepts are proposed.

2. Synchronisation via the Air-Interface

2.1 Beacon Synchronisation

For a well working TDD-system synchronisation between Node B is required. Because synchronisation is needed only on frame basis (10 ms), the complexity for HW, SW and signalling is not very high. This synchronisation concept is based on a synchronisation via the air interface. The structure of the synchronisation path is organised hierarchically. This means that there is a master synchronisation unit, the main area beacon, which provides the synchronisation timing for a whole area, e.g. a city. Therefore the main beacon is placed at position with a high antenna height, so that it can reach, coverage a large area. If an area can't be reached, an extra hierarchy level is introduced, the local sub area, where the local sub area beacon synchronises the isolated region. The local sub area beacon synchronises itself to main area beacon.

The synchronisation within a local sub area is done either by one beacon base station or by a main area beacon. All the beacon base stations of a main area are synchronised by one main area beacon. The two described synchronisation levels are implemented using either terrestrial radio links or physical lines (indoor). Each main/sub area can work as a synchronised network for itself. The highest level of synchronisation can be implemented by using e.g. direct radio links. The main advantage of this concept is that each sub area can work stand alone if a synchronisation link is lost.

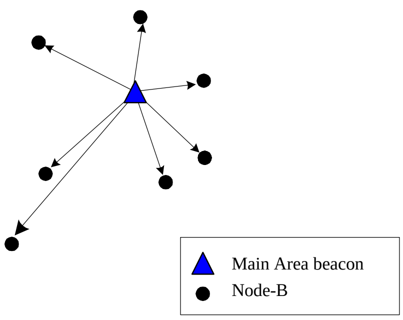

Figure** Error! Unknown switch argument.1 : **Beacon synchronisation

Node B synchronisation is done by so called beacon base stations (normal base stations with this additional capability) via the air interface. The synchronisation information is transmitted on a special synchronisation burst on a reserved TS every 50^{th} to 1000^{th} frame, which is equivalent to 0.5 to 10 seconds (capacity loss< 0.1 %). Since the coverage area of the sync. information has to be larger than that of traffic channels of this Node B the synchronisation burst has to have good correlation properties.

2.1.1 Propagation delay compensation

The propagation delay between the beacon and the Node B should be compensated. For larger networks the co-ordinates of the Node B are well known and the propagation delay can be easily determined e.g. out of a database. A round trip delay measurement for propagation delay compensation can also be an option. Another solution is to support the delay measurement with a GPS-receiver at the installation time of the Node B. In case of small networks the propagation delay is not a problem, since the cell radius is small and so the phase inaccuracy due to the propagation delay can be negligible.

2.2 Non Hierarchical Synchronisation

In contrast to the beacon synchronisation this approach doesn’t need any hierarchy relation for the synchronisation path. The main synchronisation requirement is that the phase difference between two Node B has to be within a limit. So the setpoint of regulation within a non hierarchical synchronisation system is the phase relation of the adjacent Node B.

In the following figure the model of non hierarchical synchronisation is shown. It can be seen that every Node B synchronises to all adjacent Node B.

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Figure **Error! Unknown switch argument.**~~2~~: Synchronisation model

From all the adjacent BS the phase difference to the own BS is measured and the mean value is taken as the initial value for the controlling algorithm.

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Where φ is the initial setting, n the number of adjacent BS, a_i the weighting coefficients for the adjacent BS and φ_i the estimate value of the phase relation of the adjacent BS. With the weighting coefficients a_i an individual control over the synchronisation behaviour is possible.

If e.g. a PI-controller is used in each Node B, the synchronisation is not only in the phase domain, but also in the frequency domain. The synchronisation burst rate need not to be fixed within the network, which means that a Node B can get from one specific adjacent Node B more measurement values than from another one, in order to compensate the effects of weak radio propagation characteristics. The propagation delay to the adjacent BS must be compensated . The mechanisms for this are equal to those described in the chapter **Error! Unknown switch argument.**~~2.1.1~~.

2.3 Synchronisation burst for synchronisation via the air interface

During the measurement of the synchronisation burst the RF amplifiers of the own Node B must be powered down to avoid blocking effects. Because the synchronisation burst is sent only every 50th to 1000th frame, which is equivalent to 0.5 to 10 seconds, the resulting capacity loss is negligible (< 0.1 %).

To distinguish the burst of different Node B following methods can be used:

- Code clustering, different Node B send different synchronisation bursts
- Timeslot clustering, different Node B send on different timeslots

The format of the synchronisation burst is ffs.

2.4 Conclusion

In order to have a flexible solution and to achieve a maximum performance, a combination of both concepts, Beacon synchronisation and non hierarchical synchronisation, is proposed.

3. Synchronisation Requirements

The TDD operation requires frame synchronisation, since asynchronous downlink/uplink frames may cause interference. Due to the capture effect, a mobile can get blocked by a nearby asynchronous mobile, so that it looses the connection to its Node B. There are various interference types:

- Node B cross interference
- UE cross interference
- Node B-UE cross interference

All these interference types exist for uplink and downlink and are depicted in the following figure:

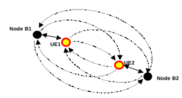


Figure 1: Interference types

To avoid all this interference it is proposed to have a frame synchronisation, which means that Node B have to be phase synchronous to each other. But also the UE to the Node B. To avoid the drift of the phase φ over time a frequency synchronisation is also necessary, since their relation is

$$j(t) = \int_{-\infty}^{t} f(t)dt$$

In the following chapters the requirements of Node B synchronisation are described.

3.1.1 Requirement for the frequency stability

Frequency stability is the ability of a Node B to transmit at the assigned carrier frequency. The proposed frequency stability of a Node B is ± 0.05 ppm, cf. 3GPP S4.02Bv0.0.2 “UTRA (BS) TDD; Radio transmission and reception”.

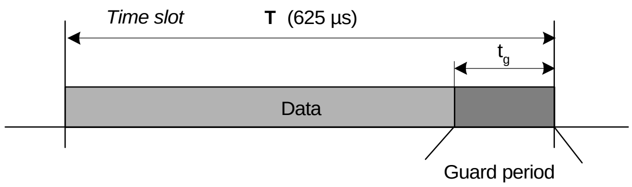
3.1.2 Requirement for the phase stability

A time slot consists of a data block and a guard period. The main purpose of the guard period (GP) is to compensate e.g. the propagation delay on a random access. This is necessary to avoid the interference to the adjacent timeslot. The length of the different burst types is listed in the following table:

Burst type	**GP [chips]**	**GP [µs]**
Burst type 1 / 2, RACH burst	96	23.4

The format of a burst is shown in the following figure:

Figure 2: Burst format



It is obvious that the tolerance of synchronisation also has an influence to the guard period t_g. Following inequality must be fulfilled, to avoid interference :

$$t_g \geq t_{prop}(r) + |t_{ta}| + |t_s|$$

Where $t_{prop}(r)$ correspondents to the propagation in dependence to the cell radius r, which changes for different environments, and t_{ta} is the failure of the timing advance regulation and finally t_s is the failure of synchronisation.

It can be seen from the relation above that the values of synchronisation accuracy t_s can be chosen according to the employed environment. This makes it possible to have a higher tolerance within an micro environment, since the required tolerance results from the inequation above:

$$t_s \leq t_g - t_{prop}(r) - |t_{ta}|$$

Since the resulting capacity C in dependence of the nominal capacity C_{nom} is given by the following formula

$$C = C_{nom} \cdot \left(1 - \frac{t_g}{T}\right)$$

Where T is the duration of a timeslot, which is 625µs. Obviously the guard period t_g must be kept as small as possible and so the synchronisation failure to minimise the capacity loss.

Thus the value of synchronisation failure is a trade off between the capacity loss and the length of the guard period.

4. Examples

4.1 Synchronisation of different Beacons

4.1.1 Direct Radio Link

In countries with flat areas the sync. between main area beacons can be realised by direct radio link on country specific frequencies. The locations of beacon Node B are situated in a way that they all have line of sight to the main area beacon. Due to this fact and because of using directional aerials for these links it is expected that no additional transmit power is needed.

4.1.2 Synchronisation via Positioning Systems

One solution for synchronisation of the main area beacon is the use of positioning systems like GPS. An alternative to GPS could be also GNSS.

4.2 Indoor Synchronisation

In indoor environments the distribution of the sync. information can be provided by e.g. LAN (optical fibres).

Another alternative is synchronisation via air interface. The problem of receiving a good sync. signal in modern buildings is the high path loss for outdoor to indoor propagation. So one Node B (Node $B_{1)}$ close to a window in the last floor of the building will be synchronised to the outstanding network. Node B_1 delivers the sync. information to a Node B in the centre of this floor. This centre Node B synchronises all other Node B of this floor and additionally the closest Node B in the floor below. The sync. of all other floors is done in the same way.

The usage of special synchronisation repeaters is also possible, to solve the problem of faded areas within the building.

4.3 Synchronisation via I_{ub}- interface

Synchronisation via the I_{ub} – interface can be used under certain conditions as an alternative to the synchronisation via the air interface.

5. Text Proposal

The synchronisation of Node B in TDD mode is applicable to both WG1 and WG4 specifications. In order to give a comprehensive picture the proposed changes are listed for all relevant specifications, however need to be approved by the relevant group.

Proposed text for WG1 S1.24 v0.1.0 "UTRA TDD Physical layer procedures"
6.2.1 Synchronisation of TDD NodeBs
...Synchronisation on a chip level is not required.

In case of Node B synchronisation via the air interface a special burst, the synchronisation burst, is used. The synchronisation burst is sent on a reserved TS every 50^{th} to 1000^{th} frame. During the reception of the synchronisation burst in a cell the transmission in this cell has to be switched off.
<Editors Note: The format of the synchronisation burst is ffs.>

Proposed text for WG4 S4.02Bv0.0.2 "UTRA (BS) TDD, Radio transmission and reception"
New Section: "Node B Synchronisation"
The TDD mode requires the synchronisation of Node Bs.
New subsection: "Minimum Requirement"
Node Bs synchronised to each other have to guarantee the following frequency / phase stability :

Frequency stability:	± 0.05 ppm
Phase stability:	± 5 µs *)

*) : For environments with small cell radius, e.g. micro environment , the phase tolerance can be even higher, since the propagation delay between Node B and UE is low. This is possible because the duration of the guard period of a timeslot is constant.