A Self-organizing Approach: Time Synchronization for the HeNodeBs in Heterogeneous Network

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Abstract In Heterogeneous Network (HetNet) for LTE/LTE-A system femtocells (HeNodeBs) are designed and implemented to extend coverage and capacity. The arbitrary usage of HeNodeBs supported for indoor coverage is linked through a third-party internet backhaul to the HeNodeB managing server, and this is a segment of the operators end. To sustain HeNodeBs to the control function IEEE1588, master slave strategy is put in effect. Nevertheless, caused by the absence of internet or unfortunate connectivity for a prolonged period HeNodeBs undergoes synchronization difficulties that leads to frequency mismatch With this paper, a kind of self-organizing method is suggested for time synchronization in Heterogeneous Network, and that is standardized using IEEE1588 master slave method along with Precision Timing Protocol (PTP). The proposed approach is two way message transmission system, adopting the Least-squares Linear Regression Algorithm (LSRA) to reduce offsets as well as frequency misalignments (drift).

Keywords Femtocell · Synchronization · Heterogeneous network · LTE/LTE-Advanced · IEEE 1588 · HeNodeB

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1 Introduction

Heterogeneous Community of LTE/LTE-A method provided expanded exposure and capacity via HeNodeBs for in-house/apartment situations. The more implementation of plug and play HeNodeBs introduces frequency misalignments due to improper synchronization or limited bandwidth connectivity. The frequency alignments are necessary to control the HeNodeBs. In Fig. 1, a Heterogeneous network scenario is illustrated [1]. To make it possible for a dependable and effective distribution associated with the multilevel network services, the accurate efficiency assured synchronization is not just only important, but also the basic requirement of the network densification technique. Considering that all HeNodeBs usually are associated by IP backhaul on the operator's network, as a result incompatible delay may perhaps take place due to changing traffic blockage. The actual synchronization connected with HeNodeBs are needed to prepare the signal obtained for reducing interference due to a number of accesses at the as time ensuring the offset of the carrier within tolerable boundaries. HeNodeBs are expected to follow the standards for minimum time and frequency synchronization which are required by various cellular standards. The requirements which dictate time synchronization are mandatory in order to manage interference as well. Which is desirable to make sure perfect assignments in synchronized networks, exclusively in Time-Division Duplex (TDD) as well as LTE-A systems. As well, the criterions and provisions aimed at the frequency synchronization be present also spirited to retain the correct structure of frequency within macro-eNodeBs and HeNodeBs. Likewise, time synchronization cutting-edge multi-hop heterogeneous network also

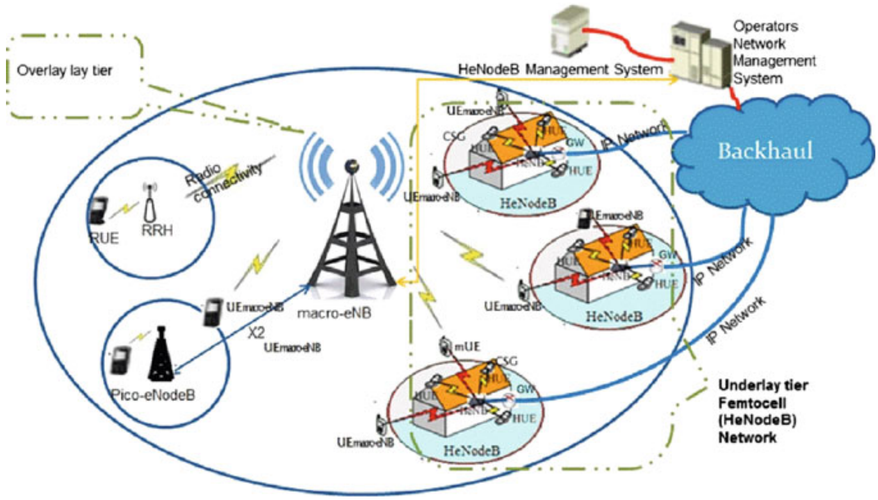

Fig. 1 Design of heterogeneous network consisting HeNodeBs, in multilevel apartment the scenario is more complex

Table 1 Heterogeneous network timing requirement

Classifications	Frequency alignments parts per billion (ppb)	Offset/phase (μs)
FDD	16	–
TDD	16	1.5
eICIC	16	1.32
LTE-A	16	0.5

requirements to circumvent the interference among the spectrum, precisely in place of Frequency-Division Duplex (FDD) [2, 3]. The heterogeneous network has more restrictive timing demands. Despite the fact of LTE FDD classifications prerequisite merely the rate of recurrence synchronization, while LTE TDD techniques be responsible for a further step requirement of 1.5 μs. Aimed at supplementary in advanced LTE-A systems, the constraint is even more unambiguous. In Table 1, the timing requirements of different access technologies [4, 5] are summarized.

All the way through orthodox 3G setups for pico-eNodeB and macro-eNodeB, synchronization was provided with TDM timing otherwise Global Navigation Satellite System (GNSS). Still, in 4G association such as HeNodeB is aligning the phases through IP backhaul comprising IEEE1588 [6], PTP [7] as well as enhanced IEEE 1588 [8]. Yet, in several cases, wherever deficiency of bandwidth or imperfect associations, the existing 1588 master-slave system has drawback. The IEEE 1588 uses pairwise messaging system via consistent medium. As a result, the delay increases and network becomes asymmetric. In Fig. 2 the IEEE1588 master/slave time synchronization method is depicted. Instead, operators pick GNSS for conveying synchronization and location credentials [2]. Usually, HeNodeBs inside apartment the GNSS signal is weaker, caused by the building

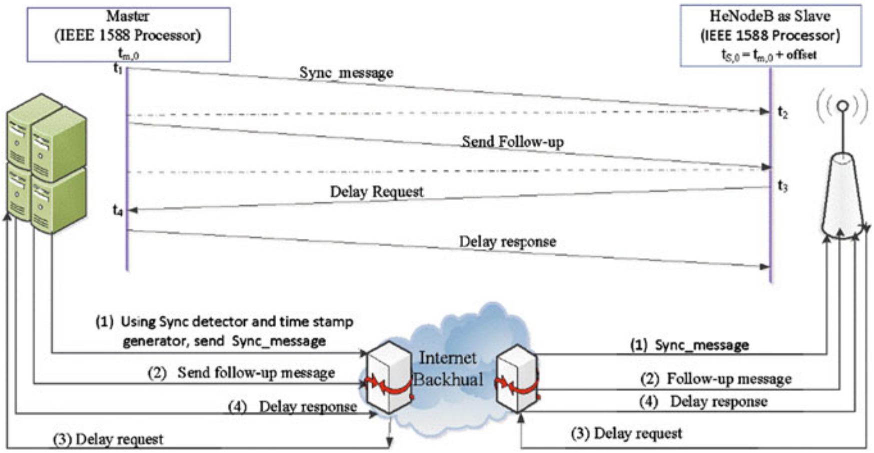

Fig. 2 IEEE1588 master/slave synchronization technique

wall width. Furthermore, some proposals are made which require extra hardware, for an example local Grandmaster. Nevertheless, extra hardware may increase cost.

This paper presents a self-organizing approach consuming Least Square Regression to synchronize the HeNodeBs in Heterogeneous Network. The proposed algorithm is novel and decentralized, thereby no need to have GNSS or hardware support anymore.

The rest of the paper is organized as: Sect. 2 deliveries the synchronization procedures and troubles to cope with the challenge, and recommended a proposed synchronization design, Sect. 3 contains encloses program arithmetic evaluation with the effect explanation, and Sect. 4 completes the paper with summary.

2 Synchronization Problems and Methods

To synchronize HeNodeBs, macro-eNodeB assistance has considered through broadcasting frame by using the Poisson clock [9]. The approach shows that each of the HeNodeBs needs to update their clocks with macro-eNodeB. The approach is able to synchronize the HeNodeBs. Yet, the tactic has succeeded up to 0.5 s offset which is beyond the requisition.

Microsecond phase aligning is speciously extreme to precise for LTE-A systems as the time duration of a single sub-frame in LTE-A is simply 1 μs [10]. In [10, 11], it is observed that by means of enhanced Inter-Cell Interference Cancellation (eICIC) even with flawed phase alignment between adjacent macro-eNodeBs for the performance tainted. Due to phase misalignment error between HeNodeBs and macro-eNodeB different interference suppression techniques performances can be disrupted. Thus stringent exactitude is obligatory for the HetNets association of LTE-A. Just in order to offset disturbance from a macro-eNodeB in order to Pico-eNodeB UEs, macro-eNodeBs every once in a while directs its own sub-frame with no data apart from some control signals and reference signals. Consequently, your moderate sub-frames usually are named Almost Blank Sub-frames (ABSs). On the other hand, macro-eNodeB must send vital system information along with Common Reference Signals (CRS) with regard to providing assistance to the resultant UEs. Using this type of tactic, HeNodeBs may plan the eICIC ABSs with regard to offering badly situated UEs. In [12], to synchronize the HeNodeBs listening supported scheme has proposed in TDD-LTE system. This scheme assumed an external synchronized clock in order to synchronize its neighbor networks. Each of the HeNodeB listens from the received signals from the neighbors and exchange message to synchronize. Moreover, in the proposed scheme considered Signal Interference to Noise Ratio (SINR) (γ_{ij}) with a threshold value because of interference barrier is shown in Eq. 1 [12].

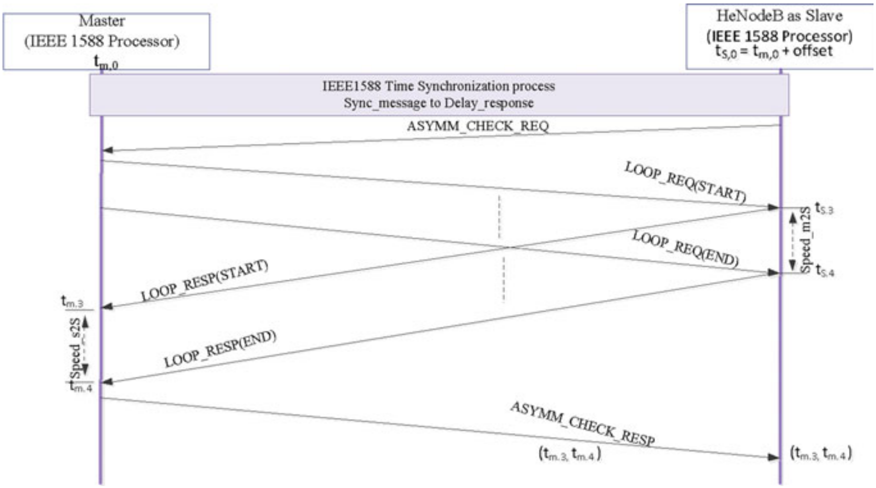

Fig. 3 Enhanced IEEE 1588 for the asymmetric ratio scheming

$$\gamma_{ij} = \frac{P_{ij}}{\sum_{k \in U,\, k \neq j} P_{ik} - \sum_{l \in T_j} P_{il} + N} \tag{1}$$

where, transmitted power is denoted P_{ij}, i and j are the HeNodeBs for the transmission and reception, N is the noise at the receivers. The performance were estimated through SINR, synchronization time. However, this approach didn't consider about the required time for the synchronization, offsets as well as frequency errors.

An enhanced time synchronization algorithm is proposed over IEEE 1588 in paper [8] to minimize the offset (bias error) in the case of asymmetric IP based communication links, for example: Asymmetric Digital Subscriber Line (ADSL) and Very- High-Data Rate Digital Subscriber Line (VDSL) which uses IEEE 1588. IEEE 1588 synchronization algorithm is improved by the extra procedure which is called the block burst transmission (in Fig. 3). This procedure is utilized in order to calculate the asymmetric ratio for the communication link. However, the new and improved IEEE 1588 still introduces an offset error which cannot be reduced to zero. Thus, certain modifications are made so that it can effectively perform over the asymmetric backhaul link. Hence better accuracy is a necessity for the asymmetric communication link of ADSL or VDSL. Some more enhancements are required so that it can efficiently perform over asymmetric backhaul link.

Mobile station Assisted (MS) technique using receiver-receiver synchronization has presented in [13] which employs the least-squares linear regression algorithm to reduce offsets. Nevertheless, in receiver-receiver synchronization, clock offset achieved 2.5 µs and the accuracy in frequency reached is up to 250 parts per billion (ppb). However, for the LTE/LTE-A heterogeneous network, the requirement is not enough as per the data in Table 1. To synchronize HeNodeBs macro-eNodeB

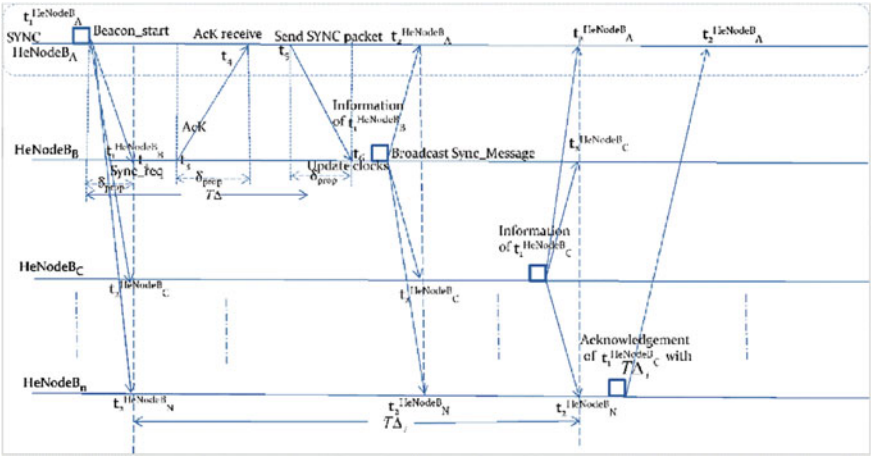

Fig. 4 Proposed synchronization approach for multi-hop synchronization scheme

assistance has considered through broadcasting frame using Reference Broadcast System (RBS) [13]. The approach shows that each of the HeNodeBs needs to update their clocks with macro-eNodeB or a reference node. The approach is able to synchronize the HeNodeBs. However, the approach has achieved larger offset than the requirement. In order to mitigate this problem, a self-organized approach is proposed which is inherited from RBS and enhanced IEEE 1855 [8] with the mechanism of LSRA to synchronize the multi-hop HeNodeBs. The proposed approach is illustrated in Fig. 4. The steps of the proposed approach is described as point wise below.

1. A coordinated synchronized HeNodeB will send *sync_beacon* to nearby *n*th *HeNodeBs*.
2. All neighboring HeNodeBs of *n*th *HeNodeBs* will receive Sync appeal and store arrival time which are $T_{n,i}^{HeNodeB_j}$ and the frequency alignment (drift) $\Upsilon_{\text{drift}}^{HeNodeB_{ij}}$, then send AcK to the reference *HeNodeB*.
3. Synchronized HeNodeB will send the correct clock reference.
4. HeNodeBs clocks will be swap as well as compare with up-to-date sync information from synchronized HeNodeB to regulate offset and frequency alignment. In every exchange of message the *n*th *HeNodeBs* directs acknowledgement to the synchronized *HeNodeB*.

3 Performance Analysis

To attain the goal of synchronization, the actual performance matric can be recognized as clock offset and clock drift. For the nth HeNodeB synchronization offset and drift is the key performance parameter. Therefore, the offset estimation can be represent in Eq. (2) applying LSRA headed for estimate and correct misalignment. Considering the propagation delay of $\mathrm{HeNodeB}_{\mathrm{B}\rightarrow\mathrm{N}}$. In the transmission reception there must have some receive delay. The delay difference can be form seeing that a Gaussian distributed random which is zero mean σ^2 variation. Due to wall attenuation in indoor environment propagation delay need to be considered. For the offsets and frequency error approximation Eq. (3) is applied.

$$\hat{\mathrm{T}}^{\mathrm{HeNodeB}_{\mathrm{B}\rightarrow\mathrm{N}}}_{\mathrm{Phase}} \cong \frac{1}{M}\sum_{i=1}^{M}\hat{\mathrm{T}}^{\mathrm{HeNodeB}_{\mathrm{B}\rightarrow\mathrm{N}}}_{\mathrm{Phase}} \tag{2}$$

$$\Upsilon_d = \left[\left(\Upsilon^{\mathrm{HeNodeB}_{\mathrm{AN}}}_{prop} - \Upsilon^{\mathrm{HeNodeB}_{\mathrm{AB}}}_{rec,i}\right) + \left(\Upsilon^{\mathrm{HeNodeB}_{\mathrm{AN}}}_{rec,i} - \Upsilon^{\mathrm{HeNodeB}_{\mathrm{AB}}}_{rec,i}\right) + \left(\Upsilon^{\mathrm{HeNodeB}_{\mathrm{AN}}}_{rec,i} - \Upsilon^{\mathrm{HeNodeB}_{\mathrm{AC}}}_{rec,i}\right)\right] \tag{3}$$

The relative frequency errors which is the drift between $HeNodeB_{A\rightarrow N}$ can be assess using Eq. (4).

$$\left(\mathrm{E}\left(\left|\emptyset_r^{\mathrm{A}\rightarrow\mathrm{N}}\right|\right)\right) = \left(\emptyset_r^{\mathrm{HeNodeB}_{\mathrm{AB}}} + \emptyset_r^{\mathrm{HeNodeB}_{\mathrm{AC}}} + \emptyset_r^{\mathrm{HeNodeB}_{\mathrm{AN}}}\right) \tag{4}$$

The performance exploration of the recommended arrangement, the simulation can be accomplished expending Monte Carlo simulation. The simulation strictures are in Table 2 [8, 12–15].

Table 2 Simulation parameters

Factors		Values
Network area		300 × 300 m^2
Number of HeNodeB		50
Distance(d)		20 m
Radius		30–40 m
Delay variation (σ)		10 μs, 15 μs
Synchronization process		15
HeNodeB radius		30
Number of samples for Monte Carlo iterations		1024
Carrier bandwidth		20 MHz
Time bandwidth factor		100 MHz
Path loss = {C*(d(a)}	Path loss exponent (a)	3
	Constant losses (C)	2

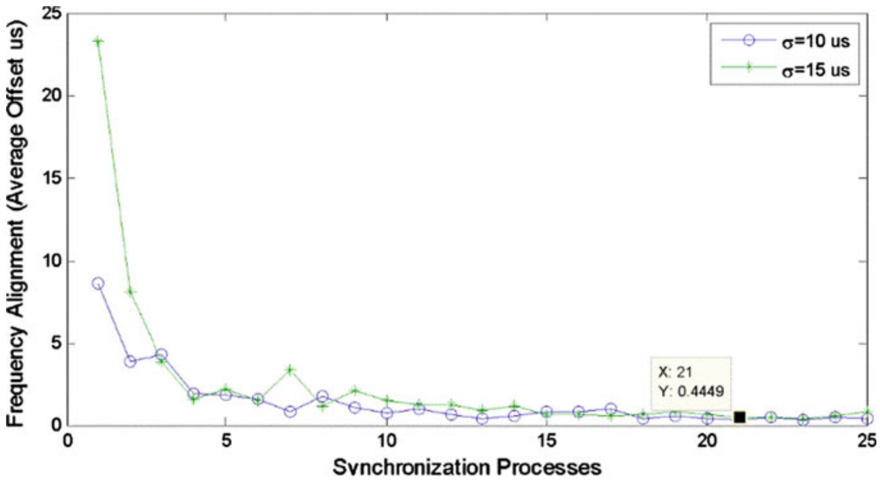

Fig. 5 Frequency alignment of offsets versus synchronization process for 15 HeNodeBs

The final result for the frequency precision of offset achieved for the LTE-A system surpasses the necessary timing as revealed in Table 1. The Fig. 5 shows the offset accuracy for the 15 HeNodeBs. The figure demonstrates that the marked data strips which is 0.44 μs in 21 synchronization process when σ is 10. However, if the number of HeNodeBs are increased during simulation (Fig. 6), the effect is a little bit different than the 15 HeNodeBs synchronization. It could be viewed in this

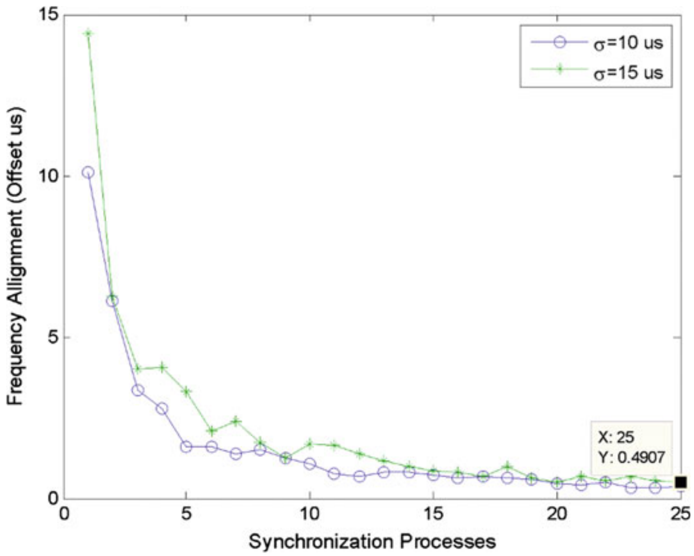

Fig. 6 Frequency alignment of offsets versus synchronization process for 20 HeNodeBs

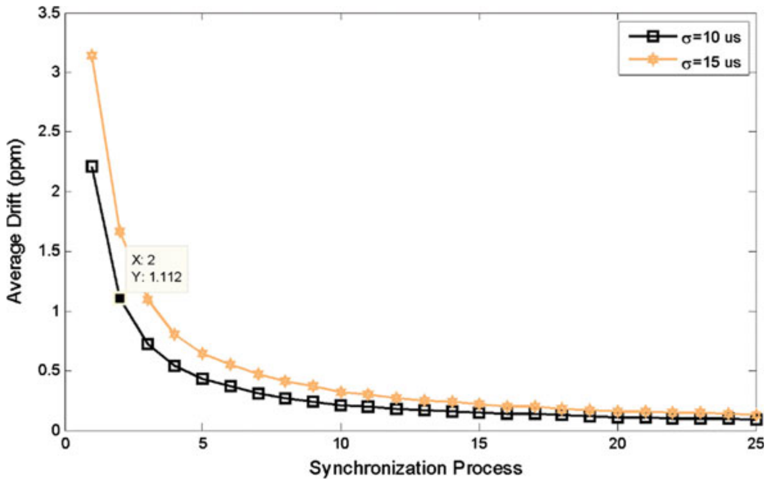

Fig. 7 Average drift versus synchronization process for 20 HeNodeBs

article that the synchronization gotten by the 25 processes, furthermore fulfills the actual LTE-A timing need.

In Fig. 7 the drift is evaluated through the 25 number of synchronization processes for $\sigma = 10$ μs, 15 μs. In 2 synchronization process, the drift accuracy (1.12 ppb) can be obtained the requirement of LTE-A.

4 Conclusion

This paper investigated IEEE1588 and RBS. It has been observed in the research that IEEE 1588 works extremely well inside Heterogeneous Network specifically for LTE/LTE-A methods; certainly where a pairwise communication is required and this depends on good wireless networks connectivity. Furthermore, for the depended media there is a big chance to enforce various delays intended for transmit and receive route, as a result asymmetry has been created, and this asymmetry cannot be predicted in pairwise synchronization processes. Thereby in the proposed scheme which is considered as prior issue. The proposed approach is able to avoid such typical delays the timing target requirement achieving (as shown in Figs. 5, 6 and 7) of the TDD, eICIC and LTE-A systems in Heterogeneous Network.

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