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A Literature Review on Conventional algorithm for PSS timing in 5G-NR

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Abstract:- **The primary aims of 5G are larger data speeds, ultra-low latency, and more dependability than its predecessor 4G. These objectives can only be realized if the mobile (user equipment) and base station create a synchronized connection, hence downlink synchronisation becomes the most critical characteristic.**

The establishment of downlink synchronisation between the user equipment and the base station relies heavily on cell search. The initial cell search for 5G-NR has been complicated by the frequency domain uncertainty of synchronisation signals and the flexibility of frame structure configuration. Therefore it becomes important to analyze the physical frame structure and knowledge about how the cell search procedure is being designed. The loss in the performance of the synchronization signals are due to the frequency offset and noise, Therefore it becomes important to develop an algorithm for PSS timing synchronization that performs better than the conventional algorithm with anti-frequency offset and anti-noise property. Not only does the improved coarse synchronisation algorithm have a high frequency offset resistance, especially for large frequency offsets, but it also has a high frequency offset resistance. Compared to the conventional algorithm, the improved fine synchronisation algorithm is more noise resistant. The following paper provides an overview of the various methodologies mentioned.

Keywords—5G-NR, Frequency offset, Primary synchronisation signal , 5G frame structure, Doppler spread, Multipath effect.

I. Introduction

5G-NR mobile communication standard presented by the 3GPP as 3GPP release 15 as in [1]-[3], presents major improvement in Long Term Evolution (LTE) standard which mainly focuses on obtaining the goals of 5G as mentioned previously. In order to achieve these goals the 3GPP has come up with a unique frame structure that can support the millimeter waves (mm Waves), which is detailed below.

5G-NR Frame structure: Based on the 3GPP the 5G-NR frame structure can be described. A frame of

10 ms is considered which has 10 subframes and each subframe of 1 ms. The 5G-NR has flexible number of slots which is obtained by the value of Numerology(μ), Therefore number of slot in a subframe can be given as 2^{μ}(which depends on the numerology). Each slot in a time frame has 14/12 OFDM symbols for normal/extended cyclic prefix.

In a frequency domain 12 consecutive subcarriers is equal to a resource block(RB), There are total 240 subcarriers which is equal to 20 RB. The combination of time-frequency structure is called as secondary synchronisation block(SSB), whose allocation details is given in table 1.1 and is being portrayed in image 1.1.

TABLE 1.1: Resource allocation of SSB

SIGNAL	OFDM	SUBCARRIER
PSS	0	56-182
SSS	2	56-182
0 value	0	0-55 and 183-255
0 value	2	48-55 and 183-191
PBCH	1,3	0-239
PBCH	2	0-47 and 192-239

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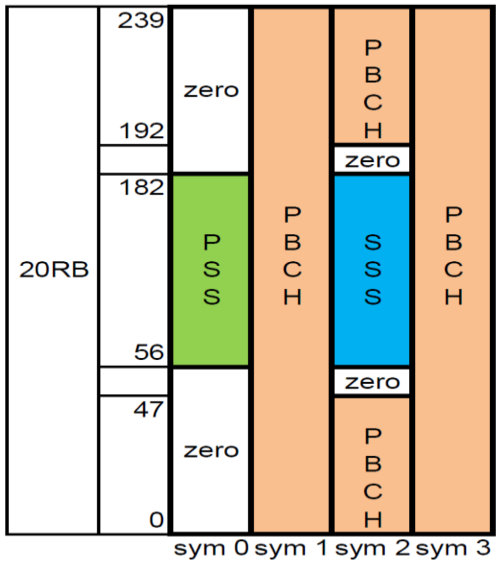
IMAGE 1.1: Illustration of SSB



Generation of PSS: In LTE(4G) PSS was generated by zadoff chu(ZC) sequence [4], whereas in 5G-NR instead of ZC sequence m-sequence is deployed. The drawback of ZC sequence is that it has a low cross correlation property hence it produces a small cell interference which makes the channel estimation complex at the receiver side, hence ZC sequence is not recommended for mmwave technology.

The m-sequence has triple autocorrelation characteristics which is useful for synchronisation. PSS is generated by the m-sequence of length 127, which is being generated in eq 1.1 keeping eq 1.2 and 1.3 as reference :-

$d_{pss}(n) = 1 - 2x(m)$……………………………........(1.1
)

$m = \left(n + 43\, N_{ID}^{(2)}\right) mod\ 127, 0 < n < 127$………….(1.2)

$x(i + 7) = \left(x(i + 4) + x(i)\right) mod\ 2$…………………........(1.3
)

Where $N_{ID}^{(1)}$ ={0,1,..355} and $N_{ID}^{(2)}$={0,1,2}.

And the shift registers initial values are given in eq 1.4:-

[x(6) x(5) x(4) x(3) x(2) x(1) x(0)]=[1 1 1 0 1 1 0]…....(1.4)

II. Literature Review On Topics Pertaining To PSS Timing Synchronization For 5G-NR

A well depth literature survey is carried out in this section pertaining to the advancement of the conventional algorithm.

A. 3GPP TS 38.211 [1].

This document provides the standard frame structure that is world widely accepted and is also explained in the previous section, further this document contains information about the sequence generation which is practically used in implementing the 5G-NR.

We get to know how the sequence such as pseudo-random sequence, Low PAPR (Peak-to-Average Power ratio) sequence is generated and also the OFDM sequence. Modulation mapping is the technique of mapping the information is binary value that is 0's and 1's generated by various modulation schemes such as BPSK,QPSK,16QAM and 265QAM. This document also contains the frame structure and physical resource that UE shall use based on the standardized antenna port number. The time-frequency structure that is SS block which is generally transmitted is burst mode at different period for example 10ms, it becomes important for the UE to synchronize with the SS burst in order to obtain the data without any modification and the structure of the SS block is learnt from this document.

B. 3GPP TS 38.212 [2].

The key takeaways are information about mapping of transport channel to the physical channel. Since the data has to move from different layers such as MAC to transport layer or vice-versa the data has to be encoded so channel coding scheme is required which should be a combination of error detection, error correcting, rate matching and interleaving. Hence we get to see deployment of different channel coding scheme for different transport channels for example low density parity check code (LDPC) for uplink and downlink transport channels.

C. Amenah Golnari . et al [4].

The author of this paper presents a time and frequency synchronizer for the LTE system which is the previous version of 5G-NR. This paper also helped in understanding the susceptible nature of OFDM symbols due to multipath and doppler effect. This paper also contains the network architecture of LTE system which helped in understanding the successor's network architecture well and firm. The algorithm for coarse and fine synchronization for LTE will be helpful in implementing it for the 5G-NR system. Further the author also introduced to a new technique of symbol detection that is using the cyclic prefix, But the problem was that the length of the cyclic prefix had to be analyzed at the receiver end and it was also observed that it fails when the N-point ifft value falls under 2048.

D. Aymen omri, et al. [5].

This paper presents about the synchronization procedure in 5G-NR, The authors have briefly explained about the frame structure of 5G-NR and how difficult it is to handle high carrier frequency which are easily distorted due the multipath effect and the need of the synchronization is understood and the authors come up with the different

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synchronization algorithm and have simulated with various parameters in concern. They analytically compared between cross correlation algorithm that is between the received signal and the locally generated signal and autocorrelation algorithm which is based on the cyclic prefix detection for the PSS and it is observed that the cross correlation algorithm works well even at high CFO offset where as auto correlation failed to do so, And it is also observed that cross correlation algorithm works well even at low SNR

E. Jing Dai, et al. [6].

In this paper the authors presents different conventional algorithms like Schmidl and cox algorithm(S&C), Minn(1) algorithm and Minn(2) algorithm. In S&C algorithm by simulating it is observed that there is a flat area near the ideal position of the correlation. In order to outperform this effect the minn(1) and minn(2) where proposed but it was observed that minn(2) was able to produce sharp spikes when compared to the minn(1) but the problem was that the spike appeared at ambiguous moment rather than just ideal moment so the authors proposed improved timing algorithm where they modified the training sequence [C,D], Where D is the reverse fold of C.

III. Analysis Of The Conventional Algorithm Based On The Survey Carried

Before going into the analysis of algorithm, It is clear that in a realistic model there is no Line Of Sight (LOS) existing between the base station (Transmitter) and the mobile device (UE) [5], The Multipath and Doppler shift comes into the picture, The multipath effect does not seems to deteriorate the signal but gives the delayed version of the signal i.e. shifted version of the signal and the Doppler shift is change in the frequency of the transmitted signal with the relative motion of the mobile device, Hereby introducing the frequency offset in the channel.

Frequency offset not only arises due to the fading channel models but also due the oscillator mismatch between the transmitter and the user equipment as in [6].

In the realistic channel model both the Multi path effect and doppler shift comes into play [7], So the received signal y(n) is introduced to an frequency offset and for test purpose it's been added to the additive white gaussian noise (AWGN), which is illustrated in eq 3.1.

Therefore, The received signal can now the equated to:-

$$y(n)=\sum_{n=0}^{\text{no of samples}-1} s(n) * \exp\left(j * 2 * pi * e * \frac{n}{N}\right) + AWGN \ldots \ldots \quad (3.1)$$

Where n= no of samples, s= Transmitted signal, e = CFO normalized by subcarrier spacing, N= Number of FFT points.

According to conventional algorithm the received sequence y(n) is subjected to sliding window cross correlation, As there are three possible N cell id's i.e. 0,1 and 2, In general three m-sequence is generated and stored in the form of local oscillator sequence and each conjugate of the sequence is subjected to sliding correlation as in eq 3.2.

It can be mathematically represented as:-

$$Corr(n)=\sum_{i=0}^{N-1} y(n+i) * X_t(i), \ldots \quad (3.2)$$

Where y(n+i) is the altered signal, X_t is the locally generated PSS sequence and t = 0,1 and 2. After performing the correlation the maximum value of the three sets is taken which tells us the value of 't'. Now the point of the highest peak is found, Which tell us the start point of the PSS [8].

Moreover, It was observed from the simulation results of this algorithm it was possible to find the value of 't' and the synchronization point when the CFO is low as 0.1 [9] and we were able to synchronize, but when the value of CFO is increased it was observed that the value of 't' is inappropriate and the synchronization point showed was unrealistic.

Therefore this algorithm can not eliminate the positive exponential components i.e. CFO and it has robustness to low CFO [10].

IV. CONCLUSION

Based on profound analysis of the mentioned papers in the section II and V it is concluded that goals of the 5G is being arduous to achieve as there does not exist an direct Line Of Sight connection in the realistic scenario, Moreover the conventional algorithm seems to work only for small CFO which is a very rare realistic scenario, Therefore it is necessary to come up with a algorithm which can completely eliminate the effect of CFO and help in detecting the PSS that is present in the zeroth OFDM symbol in the SS-block.

Firstly there is a need to create a transmitter model that strictly follows the 5G specification, should be designed and realized and further test it for low CFO with conventional algorithm and developing a improved algorithm for that works well for low CFO and large CFO, In addition a simulation result will be shown.

As it is observed that the conventional algorithm works well at low CFO it is now required to find the value of the CFO and then correct the entire signal.

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In the end the algorithm will be able to find the synchronization point of PSS which is the first step in cell search procedure.

V. ACKNOWLEDGMENT

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