5G Frame Structure

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Summary

3GPP is currently defining physical layer technologies for 5G cellular communications. New 5G services (e.g. URLLC) and new features of 5G (e.g. support of cm- and mm-bands) require new frame structures. 5G frame structures provide a fixed and a flexible part. The new structures facilitate mixed numerologies and low latency operations.

This paper describes and motivates the required new structures defined for 5G.

Introduction

3GPP is currently defining physical layer technologies for 5G cellular communications under the acronym NR (New Radio).

Potential new concepts have been studied and documented in 3GPP technical report TR 38.802 [1].

Specification work based on the report is currently ongoing at 3GPP working group RAN 1. Results are captured in specifications TS 38.201, TS 38.202, TS 38.211, TS 38.212, TS 38.213, TS 38.214 and TS 38.215 [2 – 8].

One major new feature of 5G compared to previous generations is the support of multiple numerologies by flexible frame structures.

Ultra-Reliable Low Latency Communications (URLLC), a key 5G service, requires shorter than LTE-slot structures (mini-slots).

In the following sections we first explain the timing and associated frame structures required for multiple numerologies. Then we describe initial cell search and the frame structures required for its timing.

Numerologies

One major new feature of 5G is multiple numerologies which can be mixed and used simultaneously.

A numerology is defined by its subcarrier spacing (the width of subcarriers in the frequency domain) and by its cyclic prefix.

5G defines a base subcarrier spacing of 15 kHz. Other subcarrier spacings are defined with respect to the base subcarrier spacing.

Scaling factors 2^m with $m \in \{-2, 0, 1, ..., 5\}$ define subcarrier spacings of 15 KHz * 2^m.

Table 1 compares some subcarrier spacings.

m =	-2 (ffs)	0	1	2	3	4	5
Subcarrier spacing [kHz]	3.75	15	30	60	120	240	480

Table 1: Subcarrier Spacings

The symbol and slot length will scale with the subcarrier spacing. There are either 7 or 14 symbols per slot. Cyclic prefix (CP) lengths also depend on subcarrier spacings, whereas multiple CP lengths per subcarrier spacing can still be configured.

Frame Structure

5G frame structures provide the basis for the timing of physical signals. Timing is different for the physical layer aspects:

- data block transmission
- symbol transmission
- synchronisation

5G frame structures provide a fixed overall structure for defining data block transmission timing. Radio frames and subframes are of fixed lengths (figure 1). They are chosen to be the same as in LTE, thereby allowing for better LTE-NR co-existence. In case of co-site deployment, slot- and frame structures may be aligned to simplify cell search and inter-frequency measurements. Coordination of control signals and channels in time domain will also be feasible to avoid interference between LTE and NR.

In order to support multiple numerologies independent of data block transmission timing, 5G frame structures also provide flexible substructures for defining symbol transmission timing.

Slots and symbols are of flexible lengths and depend on subcarrier spacing (figure 1). Synchronisation timing is defined in terms of fixed frame structures and in terms of synchronisation signal bursts and burst sets (see below).

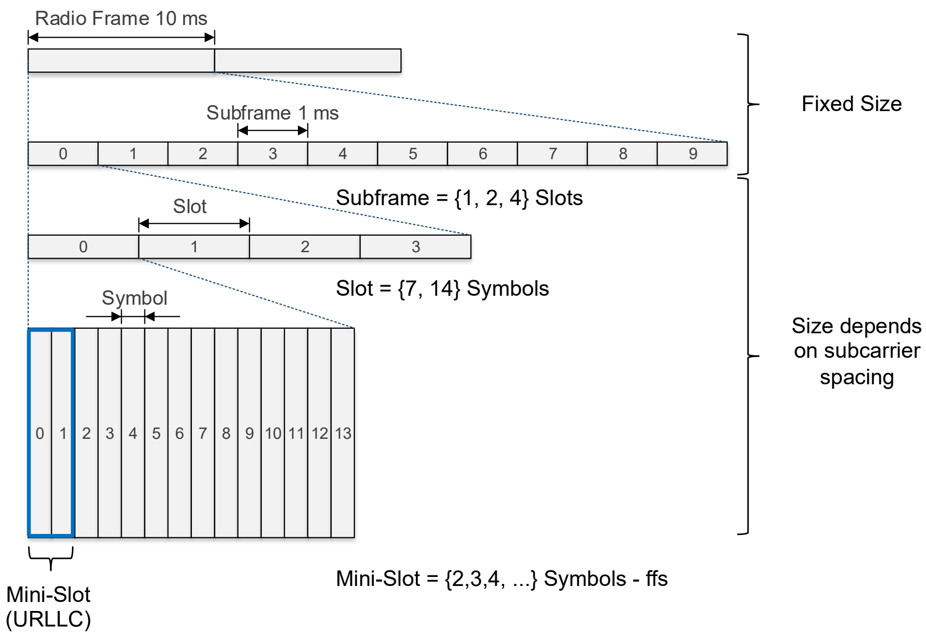

Figure 1: Frame Structure

Mini-Slots

5G defines a subslot structure called a mini-slot. Mini-slots can be used for:

- low latency applications such as Ultra Reliable Low Latency Communications (URLLC)
- operation in unlicensed bands (e.g. to start transmission directly after a successful listen-before-talk procedure without waiting for the slot boundary)

Mini-slots consist of two or more symbols (for further study - ffs), whereas the first symbol includes (uplink or downlink) control information.

For low latency support HARQ can be configured either on a slot or a mini-slot basis. For the regular frame structure used by non-delay critical services slot bundling as in LTE also possible.

Mini-slots may also be used for fast flexible scheduling of services (pre-emption of URLLC over eMBB). Mini-slots are likely to be supported by some UEs only.

Synchronisation Signals

In order to connect to the network UEs need to perform initial cell search. The objective of initial cell search is to:

- find a strong cell for potential connection
- obtain an estimate of frame timing
- obtain cell identifications
- find reference signals for demodulation

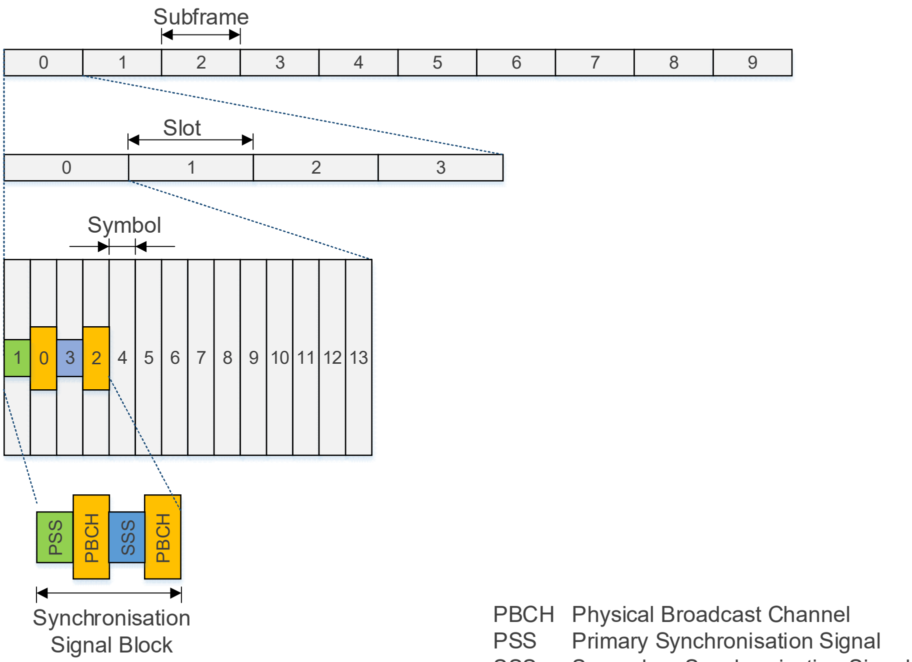

Figure 2: Synchronisation Signal Blocks (SS-Blocks)

For this purpose Primary Synchronisation Signals (PSS) and Secondary Synchronisation Signals (SSS) are used. PSS and SSS are transmitted in synchronisation signal blocks together with the Physical Broadcast Channel (PBCH). The blocks are transmitted per slot at a fixed slot location (figure 2).

During initial cell search the UE correlates received signals and synchronisation signal sequences by means of matched filters and performs the steps:

1. Find Primary Sync Sequence and obtain symbol and 5 ms frame timing.
2. Find Secondary Sync Sequence and detect CP length and FDD/TDD duplexing method and obtain exact frame timing from matched filter results for PSS and SSS and obtain cell identity from reference signal sequence index.
3. Decode PBCH and obtain basic system information.

For the support of beam sweeping, the SS blocks are organised into SS bursts and SS bursts are organised into SS burst sets that are periodically sent.

Physical Broadcast Channel

The Physical Broadcast Channel (PBCH) provides basic system information to UEs. Any UE must decode the information on the PBCH in order to access the cell.

Information provided by the PBCH for example is (ffs):

- downlink system bandwidth
- timing information within radio frame
- SS burst set periodicity
- system frame number
- other higher layer information (ffs)

Other broadcast information is mapped onto the shared channel.

Physical Mapping of SSs and PBCH

Mapping of SSs and the PBCH to physical resources is currently under discussion at 3GPP. One proposed mapping is depicted in figure 3 [9].

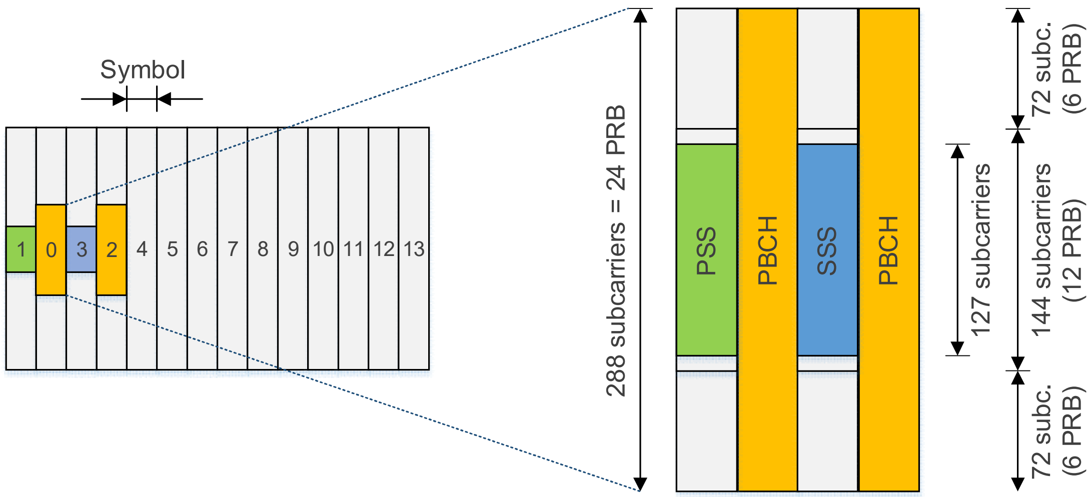

Figure 3: SS Block Physical Resources

Only 4 symbols for PSS/SSS/PBCH ensure fast acquisition times. Guard bands for PSS/SSS ensure reduced interference. A bandwidth of 24 PRBs must be supported by all 5G UEs.

SS block bandwidths depend on subcarrier spacing. Examples are given in table 2 and figure 4.

Sub-Carrier Spacing	Subcarriers for PBCH	Bandwidth for PBCH	MIn. Channel Bandwidth
15	288	4.32 MHz	5 MHz
30	288	8.64 MHz	10 MHz (ffs)
60	288	17.28 MHz	20 MHz (ffs)

Table 2: SS Block Bandwidths

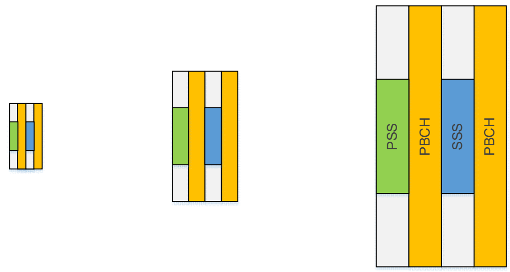

Figure 4: SS Block Bandwidths

System Information

System information is provided in a hierarchical manner. Basic cell configuration information is provided by the PBCH. Further system information is provided via the shared channel.

Full information can be obtained by the steps:

4. The UE reads the PBCH providing the basic cell configuration and finds the downlink control channel (which schedules the shared channel).
5. The UE reads the minimum system information providing scheduling information for all other system information blocks.
6. The UE reads other required system information.
7. The UE requests on demand system information, e.g. system information that is only relevant to a specific UE.

Figure 7 depicts the procedure.

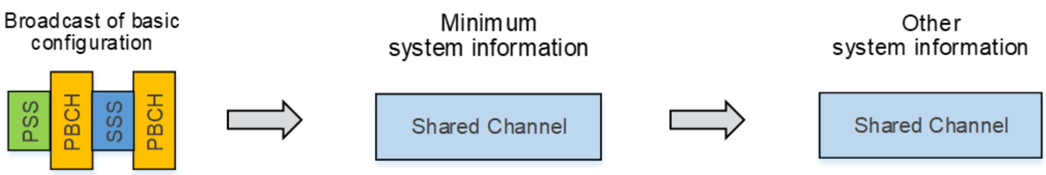

Figure 7: Obtaining Hierarchical System Information

References

[1] 3GPP TR 38.802, "Study on new radio access technology Physical layer aspects," V14.1.0, June 2017.

[2] 3GPP TS 38.201, "NR; Physical Layer; General Description," V0.0.0, May 2017.

[3] 3GPP TS 38.202, "NR; Services provided by the physical layer," V0.0.0, May 2017.

[4] 3GPP TS 38.211, "NR; Physical channels and modulation," V0.1.0, July 2017.

[5] 3GPP TS 38.212, "NR; Multiplexing and channel coding," V0.0.0, May 2017.

[6] 3GPP TS 38.213, "NR; Physical layer procedures for control," V0.0.0, May 2017.

[7] 3GPP TS 38.214, "NR; Physical layer procedures for data," V0.0.0, May 2017.

[8] 3GPP TS 38.215, "NR; Physical layer measurements," V0.0.0, May 2017.

[9] 3GPP technical contribution R1-1708720, Ericsson: "SS Block Composition and SS Burst Set Composition," May 2017.

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