6.3.3 Physical random-access channel

6.3.3.1 Sequence generation

The set of random-access preambles $x_{u,v}(n)$ shall be generated according to

$$x_{u,v}(n) = x_u\left((n + C_v) \bmod L_{\mathrm{RA}}\right)$$

$$x_u(i) = e^{-j\frac{\pi u i(i+1)}{L_{\mathrm{RA}}}}, i = 0,1,\ldots, L_{\mathrm{RA}} - 1$$

from which the frequency-domain representation shall be generated according to

$$y_{u,v}(n) = \sum_{m=0}^{L_{\mathrm{RA}}-1} x_{u,v}(m) \cdot e^{-j\frac{2\pi mn}{L_{\mathrm{RA}}}}$$

where $L_{\mathrm{RA}} = 839$ or $L_{\mathrm{RA}} = 139$ depending on the PRACH preamble format as given by Tables 6.3.3.1-1 and 6.3.3.1-2.

There are 64 preambles defined in each time-frequency PRACH occasion, enumerated in increasing order of first increasing cyclic shift C_v of a logical root sequence, and then in increasing order of the logical root sequence index, starting with the index obtained from the higher-layer parameter *prach-RootSequenceIndex*. Additional preamble sequences, in case 64 preambles cannot be generated from a single root Zadoff-Chu sequence, are obtained from the root sequences with the consecutive logical indexes until all the 64 sequences are found. The logical root sequence order is cyclic: the logical index 0 is consecutive to 837 when $L_{\mathrm{RA}} = 839$ and is consecutive to 137 when $L_{\mathrm{RA}} = 139$. The sequence number u is obtained from the logical root sequence index according to Tables 6.3.3.1-3 and 6.3.3.1-4.

The cyclic shift C_v is given by

$$C_v = \begin{cases} vN_{\mathrm{CS}} & v = 0,1,\ldots,\lfloor L_{\mathrm{RA}}/N_{\mathrm{CS}} \rfloor - 1, N_{\mathrm{CS}} \neq 0 & \text{for unrestricted sets} \\ 0 & N_{\mathrm{CS}} = 0 & \text{for unrestricted sets} \\ d_{\mathrm{start}}\lfloor v/n_{\mathrm{shift}}^{\mathrm{RA}} \rfloor + (v \bmod n_{\mathrm{shift}}^{\mathrm{RA}})N_{\mathrm{CS}} & v = 0,1,\ldots, w-1 & \text{for restricted sets type A and B} \\ \bar{d}_{\mathrm{start}} + (v-w)N_{\mathrm{CS}} & v = w,\ldots, w+\bar{n}_{\mathrm{shift}}^{\mathrm{RA}} - 1 & \text{for restricted sets type B} \\ \bar{\bar{d}}_{\mathrm{start}} + (v-w-\bar{n}_{\mathrm{shift}}^{\mathrm{RA}})N_{\mathrm{CS}} & v = w+\bar{n}_{\mathrm{shift}}^{\mathrm{RA}},\ldots, w+\bar{n}_{\mathrm{shift}}^{\mathrm{RA}}+\bar{\bar{n}}_{\mathrm{shift}}^{\mathrm{RA}} - 1 & \text{for restricted sets type B} \end{cases}$$

$$w = n_{\mathrm{shift}}^{\mathrm{RA}} n_{\mathrm{group}}^{\mathrm{RA}} + \bar{n}_{\mathrm{shift}}^{\mathrm{RA}}$$

where N_{CS} is given by Tables 6.3.3.1-5 to 6.3.3.1-7, the higher-layer parameter *restrictedSetConfig* determines the type of restricted sets (unrestricted, restricted type A, restricted type B), and Tables 6.3.3.1-1 and 6.3.3.1-2 indicate the type of restricted sets supported for the different preamble formats.

The variable d_u is given by

$$d_u = \begin{cases} q & 0 \le q < L_{\mathrm{RA}}/2 \\ L_{\mathrm{RA}} - q & \text{otherwise} \end{cases}$$

where q is the smallest non-negative integer that fulfils $(qu) \bmod L_{\mathrm{RA}} = 1$. The parameters for restricted sets of cyclic shifts depend on d_u.

For restricted set type A, the parameters are given by:

- for $N_{\mathrm{CS}} \le d_u < L_{\mathrm{RA}}/3$

$$\begin{aligned} n_{\mathrm{shift}}^{\mathrm{RA}} &= \lfloor d_u / N_{\mathrm{CS}} \rfloor \\ d_{\mathrm{start}} &= 2d_u + n_{\mathrm{shift}}^{\mathrm{RA}} N_{\mathrm{CS}} \\ n_{\mathrm{group}}^{\mathrm{RA}} &= \lfloor L_{\mathrm{RA}} / d_{\mathrm{start}} \rfloor \\ \bar{n}_{\mathrm{shift}}^{\mathrm{RA}} &= \max\left(\left\lfloor \left(L_{\mathrm{RA}} - 2d_u - n_{\mathrm{group}}^{\mathrm{RA}} d_{\mathrm{start}}\right) / N_{\mathrm{CS}} \right\rfloor, 0\right) \end{aligned}$$

- for $L_{\mathrm{RA}}/3 \le d_u \le (L_{\mathrm{RA}} - N_{\mathrm{CS}})/2$

$$\begin{aligned} n_{\mathrm{shift}}^{\mathrm{RA}} &= \lfloor (L_{\mathrm{RA}} - 2d_u) / N_{\mathrm{CS}} \rfloor \\ d_{\mathrm{start}} &= L_{\mathrm{RA}} - 2d_u + n_{\mathrm{shift}}^{\mathrm{RA}} N_{\mathrm{CS}} \\ n_{\mathrm{group}}^{\mathrm{RA}} &= \lfloor d_u / d_{\mathrm{start}} \rfloor \\ \bar{n}_{\mathrm{shift}}^{\mathrm{RA}} &= \min\left(\max\left(\left\lfloor \left(d_u - n_{\mathrm{group}}^{\mathrm{RA}} d_{\mathrm{start}}\right) / N_{\mathrm{CS}} \right\rfloor, 0\right), n_{\mathrm{shift}}^{\mathrm{RA}}\right) \end{aligned}$$

For restricted set type B, the parameters are given by:

- for $N_{\mathrm{CS}} \le d_u < L_{\mathrm{RA}}/5$

$$\begin{aligned} n_{\mathrm{shift}}^{\mathrm{RA}} &= \lfloor d_u / N_{\mathrm{CS}} \rfloor \\ d_{\mathrm{start}} &= 4d_u + n_{\mathrm{shift}}^{\mathrm{RA}} N_{\mathrm{CS}} \\ n_{\mathrm{group}}^{\mathrm{RA}} &= \lfloor L_{\mathrm{RA}} / d_{\mathrm{start}} \rfloor \\ \bar{n}_{\mathrm{shift}}^{\mathrm{RA}} &= \max\left(\left\lfloor \left(L_{\mathrm{RA}} - 4d_u - n_{\mathrm{group}}^{\mathrm{RA}} d_{\mathrm{start}}\right) / N_{\mathrm{CS}} \right\rfloor, 0\right) \end{aligned}$$

- for $L_{\mathrm{RA}}/5 \le d_u \le (L_{\mathrm{RA}} - N_{\mathrm{CS}})/4$

$$\begin{aligned} n_{\mathrm{shift}}^{\mathrm{RA}} &= \lfloor (L_{\mathrm{RA}} - 4d_u) / N_{\mathrm{CS}} \rfloor \\ d_{\mathrm{start}} &= L_{\mathrm{RA}} - 4d_u + n_{\mathrm{shift}}^{\mathrm{RA}} N_{\mathrm{CS}} \\ n_{\mathrm{group}}^{\mathrm{RA}} &= \lfloor d_u / d_{\mathrm{start}} \rfloor \\ \bar{n}_{\mathrm{shift}}^{\mathrm{RA}} &= \min\left(\max\left(\left\lfloor \left(d_u - n_{\mathrm{group}}^{\mathrm{RA}} d_{\mathrm{start}}\right) / N_{\mathrm{CS}} \right\rfloor, 0\right), n_{\mathrm{shift}}^{\mathrm{RA}}\right) \end{aligned}$$

- for $(L_{RA} + N_{CS})/4 \le d_u < 2L_{RA}/7$

$$
\begin{aligned}
n_{\text{shift}}^{RA} &= \lfloor (4d_u - L_{RA})/N_{CS} \rfloor \\
d_{\text{start}} &= 4d_u - L_{RA} + n_{\text{shift}}^{RA} N_{CS} \\
\bar{d}_{\text{start}} &= L_{RA} - 3d_u + n_{\text{group}}^{RA} d_{\text{start}} + \bar{n}_{\text{shift}}^{RA} N_{CS} \\
\bar{\bar{d}}_{\text{start}} &= L_{RA} - 2d_u + n_{\text{group}}^{RA} d_{\text{start}} + \bar{\bar{n}}_{\text{shift}}^{RA} N_{CS} \\
n_{\text{group}}^{RA} &= \lfloor d_u / d_{\text{start}} \rfloor \\
\bar{n}_{\text{shift}}^{RA} &= \max\left(\left\lfloor \left(L_{RA} - 3d_u - n_{\text{group}}^{RA} d_{\text{start}}\right)/N_{CS} \right\rfloor, 0\right) \\
\bar{\bar{n}}_{\text{shift}}^{RA} &= \left\lfloor \min\left(d_u - n_{\text{group}}^{RA} d_{\text{start}}, 4d_u - L_{RA} - \bar{n}_{\text{shift}}^{RA} N_{CS}\right)/N_{CS} \right\rfloor \\
\bar{\bar{\bar{n}}}_{\text{shift}}^{RA} &= \left\lfloor \left(\left(1 - \min\left(1, \bar{n}_{\text{shift}}^{RA}\right)\right)\left(d_u - n_{\text{group}}^{RA} d_{\text{start}}\right) + \min\left(1, \bar{n}_{\text{shift}}^{RA}\right)\left(4d_u - L_{RA} - \bar{n}_{\text{shift}}^{RA} N_{CS}\right)\right)/N_{CS} \right\rfloor - \bar{\bar{n}}_{\text{shift}}^{RA}
\end{aligned}
$$

- for $2L_{RA}/7 \le d_u \le (L_{RA} - N_{CS})/3$

$$
\begin{aligned}
n_{\text{shift}}^{RA} &= \lfloor (L_{RA} - 3d_u)/N_{CS} \rfloor \\
d_{\text{start}} &= L_{RA} - 3d_u + n_{\text{shift}}^{RA} N_{CS} \\
\bar{d}_{\text{start}} &= d_u + n_{\text{group}}^{RA} d_{\text{start}} + \bar{n}_{\text{shift}}^{RA} N_{CS} \\
\bar{\bar{d}}_{\text{start}} &= 0 \\
n_{\text{group}}^{RA} &= \lfloor d_u / d_{\text{start}} \rfloor \\
\bar{n}_{\text{shift}}^{RA} &= \max\left(\left\lfloor \left(4d_u - L_{RA} - n_{\text{group}}^{RA} d_{\text{start}}\right)/N_{CS} \right\rfloor, 0\right) \\
\bar{\bar{n}}_{\text{shift}}^{RA} &= \left\lfloor \min\left(d_u - n_{\text{group}}^{RA} d_{\text{start}}, L_{RA} - 3d_u - \bar{n}_{\text{shift}}^{RA} N_{CS}\right)/N_{CS} \right\rfloor \\
\bar{\bar{\bar{n}}}_{\text{shift}}^{RA} &= 0
\end{aligned}
$$

- for $(L_{RA} + N_{CS})/3 \le d_u < 2L_{RA}/5$

$$
\begin{aligned}
n_{\text{shift}}^{RA} &= \lfloor (3d_u - L_{RA})/N_{CS} \rfloor \\
d_{\text{start}} &= 3d_u - L_{RA} + n_{\text{shift}}^{RA} N_{CS} \\
\bar{d}_{\text{start}} &= 0 \\
\bar{\bar{d}}_{\text{start}} &= 0 \\
n_{\text{group}}^{RA} &= \lfloor d_u / d_{\text{start}} \rfloor \\
\bar{n}_{\text{shift}}^{RA} &= \max\left(\left\lfloor \left(L_{RA} - 2d_u - n_{\text{group}}^{RA} d_{\text{start}}\right)/N_{CS} \right\rfloor, 0\right) \\
\bar{\bar{n}}_{\text{shift}}^{RA} &= 0 \\
\bar{\bar{\bar{n}}}_{\text{shift}}^{RA} &= 0
\end{aligned}
$$

- for $2L_{\mathrm{RA}}/5 \le d_u \le (L_{\mathrm{RA}} - N_{\mathrm{CS}})/2$

$$n_{\mathrm{shift}}^{\mathrm{RA}} = \lfloor (L_{\mathrm{RA}} - 2d_u)/N_{\mathrm{CS}} \rfloor$$
$$d_{\mathrm{start}} = 2(L_{\mathrm{RA}} - 2d_u) + n_{\mathrm{shift}}^{\mathrm{RA}} N_{\mathrm{CS}}$$
$$\overline{d}_{\mathrm{start}} = 0$$
$$\overline{\overline{d}}_{\mathrm{start}} = 0$$
$$n_{\mathrm{group}}^{\mathrm{RA}} = \lfloor (L_{\mathrm{RA}} - d_u)/d_{\mathrm{start}} \rfloor$$
$$\overline{n}_{\mathrm{shift}}^{\mathrm{RA}} = \max\left(\left\lfloor \left(3d_u - L_{\mathrm{RA}} - n_{\mathrm{group}}^{\mathrm{RA}} d_{\mathrm{start}}\right)/N_{\mathrm{CS}} \right\rfloor, 0\right)$$
$$\overline{\overline{n}}_{\mathrm{shift}}^{\mathrm{RA}} = 0$$
$$\overline{\overline{\overline{n}}}_{\mathrm{shift}}^{\mathrm{RA}} = 0$$

For all other values of d_u, there are no cyclic shifts in the restricted set.

Table 6.3.3.1-1: PRACH preamble formats for $L_{\mathrm{RA}} = 839$ and $\Delta f^{\mathrm{RA}} \in \{1.25, 5\}$ kHz.

Format	L_{RA}	Δf^{RA}	N_u	$N_{\mathrm{CP}}^{\mathrm{RA}}$	Support for restricted sets
0	839	1.25 kHz	24576κ	3168κ	Type A, Type B
1	839	1.25 kHz	$2 \cdot 24576\kappa$	21024κ	Type A, Type B
2	839	1.25 kHz	$4 \cdot 24576\kappa$	4688κ	Type A, Type B
3	839	5 kHz	$4 \cdot 6144\kappa$	3168κ	Type A, Type B

Table 6.3.3.1-2: Preamble formats for $L_{\mathrm{RA}} = 139$ and $\Delta f^{\mathrm{RA}} = 15 \cdot 2^{\mu}$ kHz where $\mu \in \{0,1,2,3\}$.

Format	L_{RA}	Δf^{RA}	N_u	$N_{\mathrm{CP}}^{\mathrm{RA}}$	Support for restricted sets
A1	139	$15 \cdot 2^{\mu}$ kHz	$2 \cdot 2048\kappa \cdot 2^{-\mu}$	$288\kappa \cdot 2^{-\mu}$	-
A2	139	$15 \cdot 2^{\mu}$ kHz	$4 \cdot 2048\kappa \cdot 2^{-\mu}$	$576\kappa \cdot 2^{-\mu}$	-
A3	139	$15 \cdot 2^{\mu}$ kHz	$6 \cdot 2048\kappa \cdot 2^{-\mu}$	$864\kappa \cdot 2^{-\mu}$	-
B1	139	$15 \cdot 2^{\mu}$ kHz	$2 \cdot 2048\kappa \cdot 2^{-\mu}$	$216\kappa \cdot 2^{-\mu}$	-
B2	139	$15 \cdot 2^{\mu}$ kHz	$4 \cdot 2048\kappa \cdot 2^{-\mu}$	$360\kappa \cdot 2^{-\mu}$	-
B3	139	$15 \cdot 2^{\mu}$ kHz	$6 \cdot 2048\kappa \cdot 2^{-\mu}$	$504\kappa \cdot 2^{-\mu}$	-
B4	139	$15 \cdot 2^{\mu}$ kHz	$12 \cdot 2048\kappa \cdot 2^{-\mu}$	$936\kappa \cdot 2^{-\mu}$	-
C0	139	$15 \cdot 2^{\mu}$ kHz	$2048\kappa \cdot 2^{-\mu}$	$1240\kappa \cdot 2^{-\mu}$	-
C2	139	$15 \cdot 2^{\mu}$ kHz	$4 \cdot 2048\kappa \cdot 2^{-\mu}$	$2048\kappa \cdot 2^{-\mu}$	