Frame structure simplified 2g 3g 4g 5g

The evolution of cellular network frame structures represents a shift from **rigid time-division architectures (2G)** to **massively flexible, multi-dimensional grids (5G)**. Over the generations, the way data is packaged and sent over the air has changed fundamentally to accommodate faster speeds and lower latency.

Here is a simplified breakdown of the radio frame structure for each generation.

2G (GSM): Rigid Time Slices

2G networks rely on **TDMA (Time Division Multiple Access)**. The air interface splits a single frequency channel into strict time segments.

- **The Frame:** One basic TDMA frame lasts exactly **4.615 milliseconds**.
- **The Slots:** Each frame splits into **8 time slots**. One user is assigned exactly one time slot to transmit their voice or data packet.
- **The Scale:** Multiple frames stack up to form larger cycles (Multiframes, Superframes, Hyperframes) to keep the base station and phone synchronized.

3G (UMTS): Continuous Code Streams

3G moved away from strict time slicing to **WCDMA (Wideband Code Division Multiple Access)**. Instead of waiting for a turn in time, everyone transmits simultaneously on the same frequency, separated by unique digital codes.

- **The Frame:** One radio frame lasts exactly **10 milliseconds**.
- **The Slots:** Each frame divides into **15 slots** (each lasting 0.667 ms).
- **The Scale:** Inside these slots, data is not measured by time blocks but by "chips" (the code bits). A slot contains **2,560 chips**, meaning time is simply used to regulate power levels and synchronize data streams rather than dividing users.

4G (LTE): The Time-Frequency Grid

4G introduced **OFDMA (Orthogonal Frequency Division Multiple Access)**, changing the frame structure from a single stream into a two-dimensional grid of time and frequency.

- **The Frame:** The baseline radio frame is **10 milliseconds** long.
- **The Subframes:** The frame splits into **10 subframes**, each lasting **1 millisecond**.
- **The Slots & Symbols:** Each subframe contains **2 slots** (0.5 ms each). Inside each slot sit **7 OFDM symbols** (or 6 under poor signal conditions).
- **The Resource Block (RB):** The smallest assignable unit of data. It is locked at **12 subcarriers** wide (180 kHz total bandwidth) and **1 slot** long (0.5 ms).

5G (NR): The Adaptable Chameleon

5G keeps the outer skeleton of 4G but removes all internal rigidity. It introduces **Flexible Numerology**, which allows the network to shrink or stretch the inner pieces of the frame to prioritize either extreme speed or ultra-low latency.

- **The Frame & Subframe:** Exactly like 4G, a frame is **10 milliseconds** and a subframe is **1 millisecond**.
- **The Flexible Slots:** Instead of a fixed number of slots per subframe, the slot count scales based on the subcarrier spacing (SCS):
    - **15 kHz spacing (Standard):** 1 slot per subframe (1 ms long, matching 4G).
    - **30 kHz spacing (Mid-band):** 2 slots per subframe (0.5 ms long).
    - **60 kHz spacing (High-band):** 4 slots per subframe (0.25 ms long).
    - *Note:* Higher spacing shrinks slot length, meaning data uploads faster and latency drops.
- **The Symbols:** Every single 5G slot is locked at **14 OFDM symbols**, regardless of how short the slot becomes.

Side-by-Side Comparison

Feature	2G (GSM)	3G (UMTS)	4G (LTE)	5G (NR)
Core Tech	TDMA	WCDMA	OFDMA	OFDMA (Flexible)
Radio Frame	4.615 ms	10 ms	10 ms	10 ms
Subframe Length	N/A	N/A	1 ms	1 ms
Slots per Frame	8 slots per frame	15 slots per frame	20 slots per frame	Variable (10, 20, 40, up to 160)
Core Allocation	1 Time Slot	1 Channel Code	Resource Block Grid	Dynamic Resource Block

** End of Page