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Right-Sized 5G: The Economics of a Smaller Radio

How 3GPP carved roughly two-thirds of the cost out of an NR device without inventing a new air interface, where RedCap and eRedCap sit between LPWA and full 5G, and an honest read of what is shipping in 2026 — fourteen launched markets, and a Cat-4 fallback still soldered onto every module.

AUTHOR
5G/6G Academy Research

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***Abstract*—Not every connected thing needs a gigabit, and most cannot afford one. 5G's answer is Reduced Capability — RedCap — a device class that reaches full-NR economics not by changing the waveform but by removing what a sensor will never use: bandwidth, a receive antenna, full duplex, fast processing. 3GPP's study quantified each cut, and combined they take roughly 67% of the cost out of a reference NR device. This paper walks the engineering lever by lever, places RedCap and its Release-18 sibling eRedCap on the capability ladder between low-power wide-area IoT and full 5G, and reads the 2026 market honestly: GSA counts 42 operators across 27 countries investing and fourteen with commercial RedCap services live, the first US launch dating to late 2024 on Qualcomm's Snapdragon X35. The cautions matter as much as the milestones. eRedCap — the variant that actually attacks LTE Cat-1 cost, capping throughput at 10 Mbps with a data channel narrowed to about 5 MHz — has chipsets only now emerging and volume modules expected in 2027; every shipping RedCap module still carries an LTE Cat-4 fallback, which tells you the cost cliff is not yet fully crossed. RedCap is real, deployed, and still maturing — exactly the stage where planners make expensive mistakes.**

1. Why a Smaller 5G Had to Exist

5G New Radio was designed at the top of the market — wide carriers, many antennas, low latency, gigabit peaks. That design is wasted on a water meter, and worse than wasted on a battery-powered sensor that must last years. For a decade the low end belonged to LTE's reduced classes (Cat-1, Cat-1bis) and the low-power wide-area technologies NB-IoT and LTE-M. But as operators plan to refarm LTE spectrum, an awkward gap opened: the cheap 4G IoT tiers have no native 5G successor, and a full NR modem is far too expensive — and too power-hungry — for the devices that fill that gap.

The 3GPP study that defined the fix, TR 38.875, started by writing down what it was cutting from. A reference NR device in the FR1 paired-spectrum (FDD) band assumes **two receive antennas and 100 MHz of bandwidth**; in unpaired TDD it assumes four receive antennas; in millimetre-wave FR2, two antennas across 200 MHz [1]. Those assumptions are why a 5G modem is expensive. Reduced Capability — "RedCap," sometimes "NR-Light" — is the deliberate, standardized removal of the assumptions a simple device will never exercise. Crucially, it removes capability, not compatibility: a RedCap device speaks ordinary NR to an ordinary gNB. No new waveform, no new core, no separate network. That is the whole trick, and it is why RedCap shipped fast.

2. The Engineering: Four Cuts, Two-Thirds the Cost

TR 38.875 priced each simplification against the reference device, and Fig. 1 shows the result for the FR1 FDD case. The biggest single saving is the one that sounds least dramatic: dropping from two receive antennas to one cuts roughly **37%** of device cost, because a receive chain is filters, mixers, an ADC and the baseband behind it — an entire signal path deleted [1]. Narrowing the carrier from 100 MHz to **20 MHz** removes about **31.9%** (mostly in the baseband, which scales with the number of resource blocks processed) [1]. Allowing **half-duplex FDD** — the device never transmits and receives at once, so it needs no expensive duplexer — saves around **6.8%**, and **relaxed processing timelines** (doubling the time the device has to decode and respond) trims roughly **6%** more from the baseband [1].

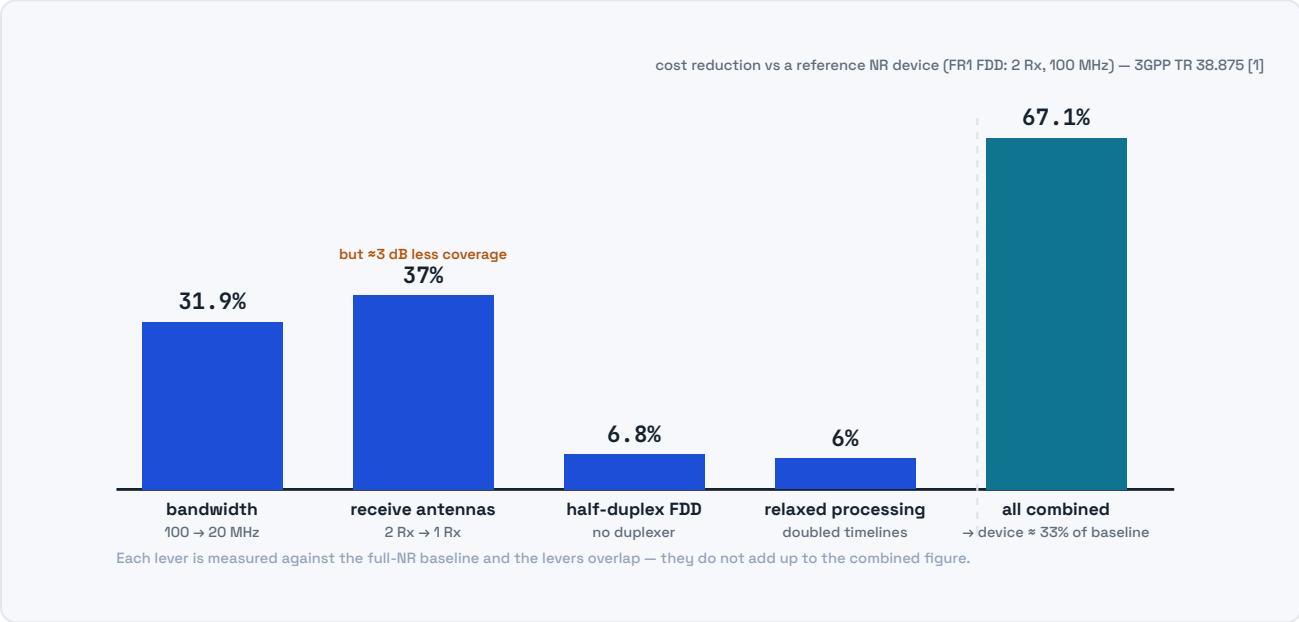

Fig. 1. The four RedCap cost levers from TR 38.875 (FR1 FDD), each measured against a reference NR device. Combined, they remove about 67% of device cost — but because the levers overlap, the individual figures do not simply add. The antenna cut is the largest, and the one with a coverage price [1].

Combined, the FR1 FDD configuration — 20 MHz, one receive antenna, one MIMO layer, half-duplex, relaxed processing — reaches a **67.1% total cost reduction**, leaving a device at roughly a third of full-NR complexity [1]. But the chart hides a bill, and honest planning surfaces it. Deleting the second receive antenna costs around **3 dB** of receive combining gain — real coverage, especially at the cell edge and indoors where IoT devices love to live. 3GPP recognized this and added coverage-recovery work, but the tradeoff is structural: the cheapest RedCap device is also the one that hears the network least well. You buy the saving in decibels.

3. RedCap, eRedCap, and the Capability Ladder

Release 17 defined RedCap; Release 18 added **eRedCap** ("enhanced," though "economy" is closer to the intent) to reach further down. The two share a stack — eRedCap devices "operate essentially in the same way" and can apply the same simplifications [4] — but eRedCap adds a hard throughput cap. Every eRedCap device is limited to **10 Mbps peak in both downlink and uplink, regardless of what else it supports** [3], [4]. The implementation detail is elegant: the radio still supports 20 MHz, but the resource blocks used for *data* are limited to roughly **5 MHz** worth — so the RF front end stays

standard while the costly baseband shrinks [4]. The target is explicit: the LTE Cat-1 niche (10 Mbps down, 5 up), with requirements aligned so a single module can serve both 4G Cat-1/1bis and 5G eRedCap during the long transition [4].

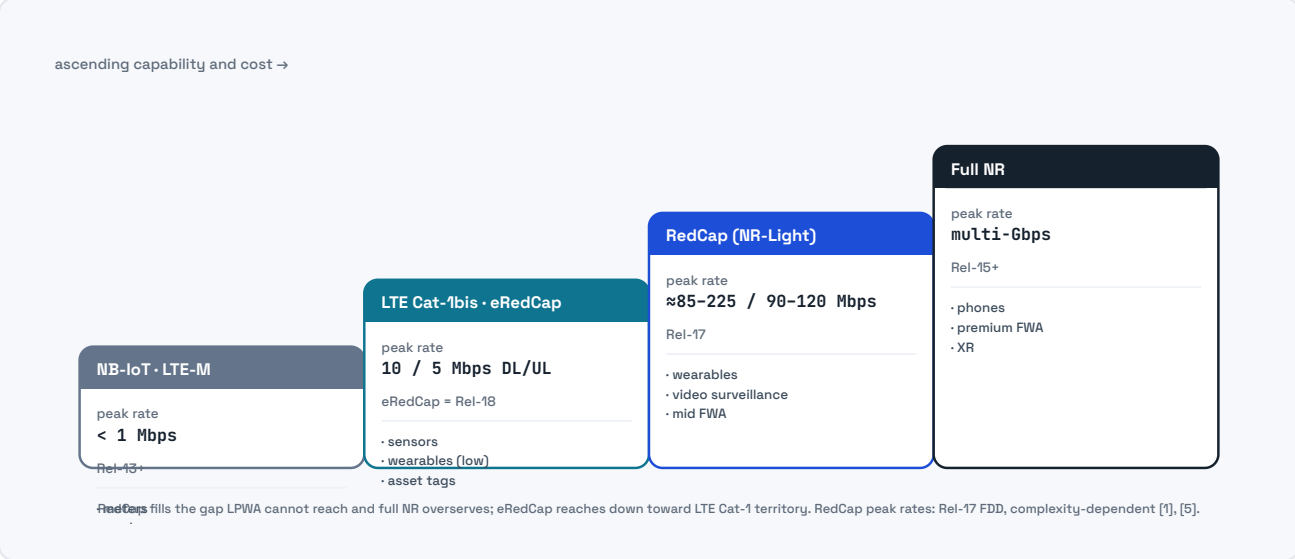

Fig. 2. The capability ladder: RedCap fills the gap LPWA cannot reach and full NR overserves; eRedCap reaches down toward LTE Cat-1 territory. RedCap peak rates are Rel-17 FDD figures and depend on device complexity [1], [5]. Table 1 gives the side-by-side detail.

TABLE 1 · The reduced-capability device classes, side by side [1], [4], [5]

Attribute	LTE Cat-1bis	eRedCap (Rel-18)	RedCap (Rel-17)	Reference NR (FR1 FDD)
Max bandwidth	~1.4 MHz	20 MHz RF / ~5 MHz data	20 MHz	100 MHz
Receive antennas	1 Rx	1 Rx (option)	1 or 2 Rx	2 Rx
Peak DL / UL	10 / 5 Mbps	10 / 10 Mbps (capped)	≈85–225 / 90–120 Mbps	multi-Gbps
3GPP basis	LTE	NR, Release 18	NR, Release 17	NR, Release 15+
Status, mid-2026	shipping (4G)	chipsets emerging; volume ~2027	commercial in 14 markets	shipping
Where it fits	trackers, low-rate IoT	sensors, simple wearables, the Cat-1 successor	wearables, video, mid-tier FWA	phones, premium FWA, XR

The study's three reference use cases map cleanly onto these tiers and explain the design choices. **Industrial wireless sensors** need under 2 Mbps but demand 99.99% availability and, for safety functions, 5–10 ms latency — bandwidth is trivial, reliability is everything [1]. **Video surveillance** is the opposite: 2–4 Mbps for economic cameras up to 7.5–25 Mbps for high-end, uplink-heavy, latency-tolerant (>500 ms acceptable) [1]. **Wearables** want 5–50 Mbps down but must sip power — battery life measured in days, ideally one to two weeks [1]. Sensors and simple wearables are eRedCap's territory; richer wearables, cameras, and mid-tier fixed-wireless are RedCap's.

4. What Is Actually Shipping in 2026

RedCap crossed from specification to commercial reality on the usual timeline — about two years after the Release-17 freeze. By the GSA's April 2026 industry update, **42 operators across 27 countries were investing** in RedCap, and **fourteen had launched commercial services**: Optus (Australia), Rogers/Fido (Canada), all three Chinese majors, stc (Kuwait), Dito (Philippines), T-Mobile and AT&T (United States), Telefónica and Deutsche Telekom (Germany), SoftBank (Japan), M1 (Singapore), MasOrange (Spain), and e&/Etisalat (UAE) [5]. The US first arrived in late 2024, when T-Mobile and TCL shipped the LINKPORT IK511 modem built on Qualcomm's **Snapdragon X35** — the first commercial RedCap modem-RF system [6], [7]. Read GSA's counts with the usual care: "investing" spans trials to live service, and a launch is network capability, not device volume.

The silicon tells the more honest story. RedCap-ready platforms now span Qualcomm, MediaTek, ASR and Sequans, and modules from vendors like Quectel are in market — but note what those modules are: the Quectel RG255 family pairs 5G RedCap with an **LTE Cat-4 fallback** [8]. That fallback is the tell. When the cheaper 5G radio still needs a 4G radio soldered beside it for coverage and roaming, the cost cliff that RedCap was meant to eliminate has been lowered, not removed. **eRedCap** — the variant that genuinely attacks the Cat-1 price point — is earlier still: Sequans showed a third-generation eRedCap chip at MWC 2026, and Sony Semiconductor Israel's Altair unit (spun off in April 2026 with $50M led by Pitango) has its ALT1550 eRedCap modem in advanced silicon testing [10]. Ericsson and the trade consensus put eRedCap commercial deployment in **2027**, with volume modules following — so a 2026 IoT design that needs eRedCap economics is designing against a roadmap, not a shelf [9], [10].

5. The Honest Part: Real, Deployed, Still Maturing

It is tempting to file RedCap under "done" — fourteen markets, real chips, a clear spec. The discipline is to hold two facts at once. RedCap *is* genuinely shipping and genuinely useful; it is also at the precise maturity stage where the gap between the brochure and the bill of materials is widest. Three honest caveats belong on every planning slide.

First, **the cost story is still maturing**. No public, verifiable RedCap-module price was available for this paper, and the Cat-4 fallback in shipping modules means today's RedCap device is not yet the stripped-down, single-radio unit the standard envisions — that device is eRedCap, and it is a 2027 story [4], [8]. Second, **the forecast numbers are softer than they look**. Cellular IoT overall is forecast to surpass 7 billion connections by 2030 at roughly 11% CAGR, with broadband and critical IoT (4G/5G) connections roughly doubling toward 4.3 billion (Ericsson Mobility Report, November 2025) — but Ericsson has at times excluded RedCap-specific counts from that headline forecast, so resist any precise "RedCap will be N billion devices" claim; none we found rests on audited ground [9]. Third, **coverage is a design parameter, not a footnote**: the single-receive-antenna device that hits the best cost saves it in link budget, which matters most for the deep-indoor and rural sensors RedCap courts (§2).

The quiet upside, conversely, is **fixed wireless access**. A RedCap radio's 85–225 Mbps is plenty for an entry-tier home or small-business FWA gateway at a fraction of a full-NR module's cost — a use case that barely appears in the IoT framing but may move more units than any sensor. Watch it.

6. Planning Guidance: Match the Tier to the Job

The decision is rarely "RedCap or not." It is "which rung of the ladder," and the answer follows from three questions. **What data rate, honestly?** Below ~1 Mbps with multi-year battery life, stay on NB-IoT or LTE-M — RedCap is overkill and shortens battery life. Around 10 Mbps with a tight bill of materials and a 4G migration path, eRedCap is the target — but design for 2027 silicon, and use LTE Cat-1bis (or dual-mode modules) as the bridge until then [4], [9]. Tens to low-hundreds of Mbps — wearables, cameras, mid-tier FWA — is RedCap's sweet spot today [1], [5]. Above that, you want full NR.

What coverage, and where? If devices live deep indoors or at the rural edge, budget for the ~3 dB the single-antenna device gives up, or specify a two-Rx RedCap variant and pay for it (§2). **What timeline?** RedCap is procurable now in the fourteen launched markets; eRedCap is a 2027 procurement with a 2026 evaluation window [5], [9]. The throughline for engineers: RedCap is the first 5G device class designed by subtraction, and subtraction has consequences you can read straight off TR 38.875 — every decibel and every dollar saved was removed from somewhere specific. Match the tier to the job, account for the coverage you traded away, and treat eRedCap as the part of the story that is still being written. The radio got right-sized. Make sure your plan is too.

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