sigfox

Sigfox device cookbook: communication configuration

November 2018

Acronym	Definition
ACK / NACK	Acknowledged/Not acknowledged
API	Application Programming Interface
B, B/s	Byte, Bytes per second
DL	Downlink or Download, i.e communication from network to device
EIRP	Equivalent Isotropic Radiated Power
GCD	Greatest Common Denominator
LBT	Listen Before Talk
LQI	Link Quality Indicator
Msg(s)	Message(s)
QoS	Quality of Service, usually expressed in transport success rate for Sigfox
Radio burst	Radio emission over the air interface
RC	Radio Configuration (Sigfox regional radio parameters variant)
Transmission	Action of transmitting a Sigfox message over the air interface (with one or several radio bursts)

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Foreword

You have decided to run the IoT challenge with Sigfox connectivity. Good choice! Sigfox technology offers unrivaled device battery life and quality of service for a wide variety of situations, including use cases requiring small and infrequent transmissions. So now you're probably wondering what to tweak to make the best application. How to avoid traps? Where to get advice on how to start? What are the options? Which is most efficient? What are the limits? This cookbook is for you - it's not a specification and it's not about one-size-fits-all solution ; it's about understanding system balance, making simple parameter associations and smart choices to maximize your connection experience!

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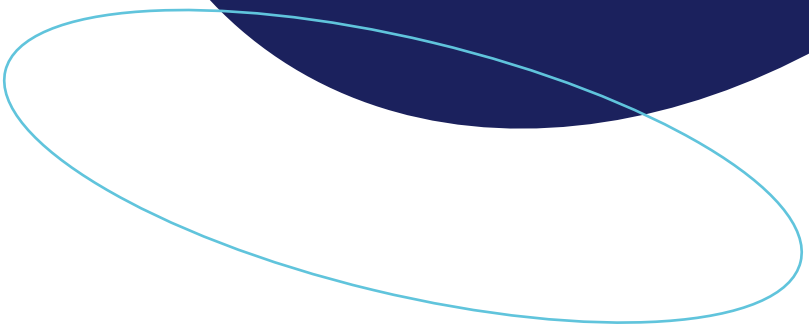
You're probably familiar with the principles of cooking! That different proportions of the same set of ingredients makes the difference between a tasty dish and a nasty one! And what about cooking with exotic products you've never tasted before? The chances of a successful result are slim, unless you use a good recipe and get the right proportions to begin with. We're engineers of course, not chefs! And our dishes are connected objects. Our basic ingredients are technical parameters. Not all of us are telecoms professionals, but we're definitely all aiming to design successful products!



This set of IoT cooking recipes focuses on configuring transmissions over Sigfox. So, what are our ingredients here? A half dozen transmission parameters that fall naturally into 3 categories:

- High-level behavioral parameters selected by device firmware: communication periodicity and RC selection.
- Low-level protocol parameters available as Sigfox library API parameters: firmware requests transmission by calling the Sigfox modem library API, with payload, single or multiframe scheme and download request.
- pure radio characteristics: radiated power (grouped into power classes) and optional power adjustments.

We will be cooking different flavors: energy savings, operational lifetime and quality of service, not forgetting that size and cost are a natural complement to energy savings. Our basic recipes are generic, and real life is of course never that simple! Remember that a recipe is just a starting point, you have to adjust it to your taste! So read through the recipes, pick your favorite ones, try out to see if it works as expected, observe and tweak a little more!

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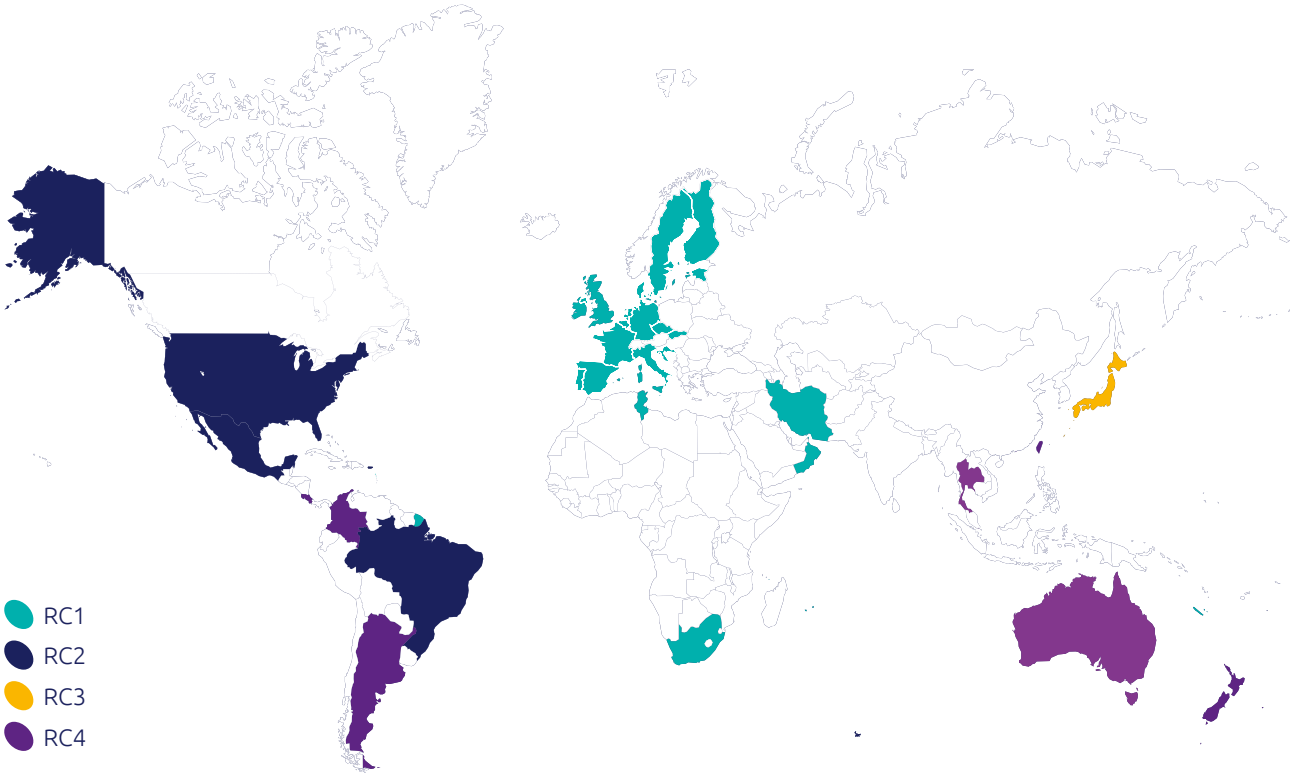
1 Radio Configuration selection



Example of RC per country on November 2018.
To find an updated list of RC, please visit ***build.sigfox.com/sigfox-radio-configurations-rc***

Before you start, list all the continents and countries where your devices will be commercialized and operated: the hardware capability and transmission configurability must be provisioned, since operating frequencies, radio access methods, emission power and bitrate are fragmented across the world. To facilitate radio parameter management, Sigfox has defined sets of operating parameters for specific continents or large groups of compatible countries, called Radio Configurations, or RCs. RC1 designates the operating parameters in Europe, the Middle East and Africa; RC2 is for North America, Mexico and Brazil; RC4 is for a large part of Latin America and most of Asia. Japan (RC3) and Korea (RC5) are managed separately. If you're not sure of the RC for a particular country, check Sigfox dedicated web resources.

If your device is traveling to countries with a compatible regulation, i.e. belonging to the same Sigfox RC, the set of operating parameters is unique and can be static. No specific action is required in this case and roaming over Sigfox is seamless.

If a device is traveling to countries managed with different Sigfox RCs, it must embark the Sigfox-dedicated Monarch function which confers the ability to acquire local operating spectrum conditions and adapt device transmission behavior for local spectrum regulation conformance. Monarch implementation has hardware, software and energy impact; dedicated guidelines are provided in a separate application note.

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2 Designing an efficient traffic model

Your use case involves traffic volume, density requirements and a certain level of flexibility. You know this better than we do. So, to design an efficient Sigfox traffic model, you need a good match between your use case, our ingredients, and external constraints!

The ingredients for cooking a good traffic model are payload and periodicity. The set of constraints includes energy efficiency, regulatory compliance and billing terms, as illustrated in figure1.

Let's briefly review these aspects and prepare to cook our first recipes!

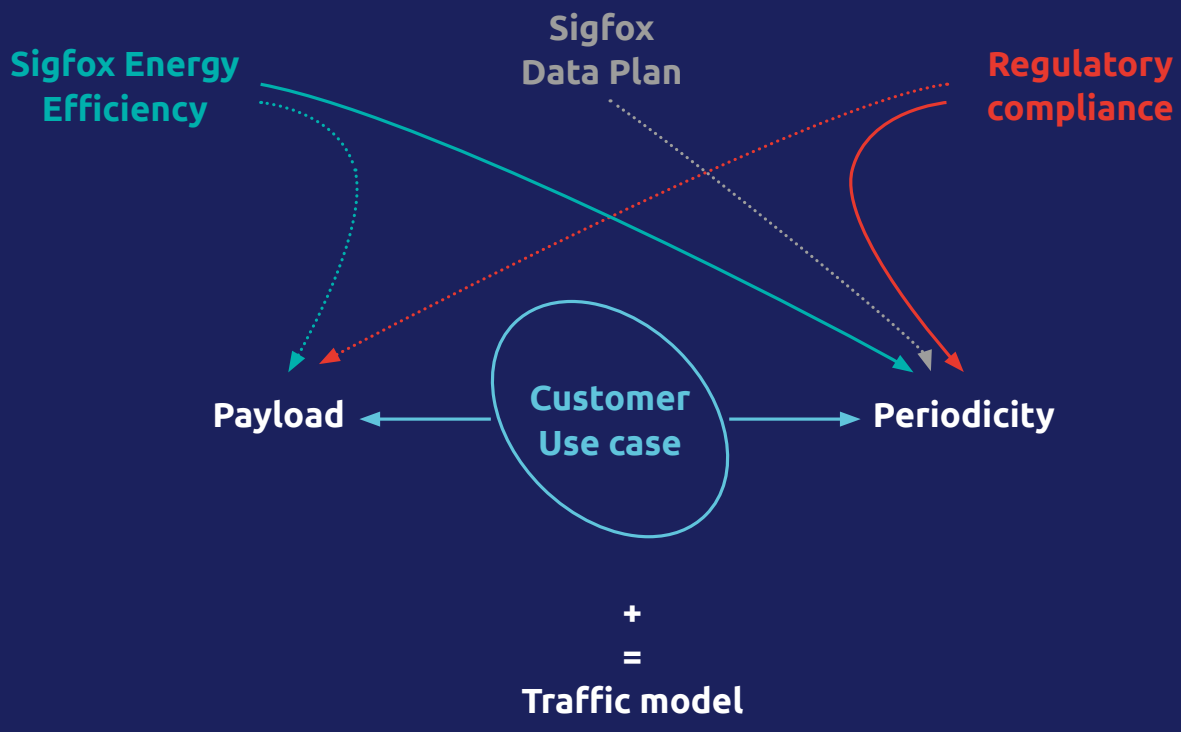

Figure1: select a traffic model based on your use case and external constraints

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2.1 Sigfox Radio link budget

Transmission periodicity

Select the required device transmission periodicity based on your use case, bearing in mind that more frequent transmissions use more energy, which means shorter battery life.

Transmission periodicity can be predictive or non-predictive, evenly or unevenly spread, and involve short or long periods of time. Just make sure you stay within the regulatory limits. In practice, most metering devices implement evenly-spread periodic transmissions ranging from 1 per day to 1 every 10 minutes, while alarm and tracking devices generate a periodic series of transmissions upon a specific event, and are silent the rest of the time.

The important point is that there is no specific Sigfox-related constraint - transmission over Sigfox is purely on demand. Just remember to avoid synchronous device operation, simultaneous device population transmissions and device synchronization over the network. The device's natural time base drift, in fact, is advantageous for Sigfox operation, so why would you engineer costly synchronous implementation when we've already engineered a whole system to save you the effort?

Payload size

Select your required transmission payload content up to a limit of 12 bytes per transmission. Sigfox protocol has predefined transmission lengths, so where a payload falls between 2 lengths, the free "space" is filled with protocol padding. Example: where you provide 9 bytes for transmission, 3 bytes of padding are added by the protocol firmware to generate a 12-byte transmission.

Why does this matter? If you have strict energy efficiency constraints, you can optimize by providing payloads of 1, 4, 8 or 12 bytes to avoid padding.

Transmission times are provided in table 1, for information.

Payload length	Frame Transmission Time	
	RC1/RC3/RC5	RC2/RC4
<1bit	1.1 seconds	190 ms
2 bits - 1 byte	1.2 seconds	200 ms
2 - 4 bytes	1.45 seconds	250 ms
5 - 8 bytes	1.75 seconds	300 ms
9 - 12 bytes	2 seconds	350 ms

Table 1: (rounded) transmission time vs. payload length

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2.2 Throughput target

Have you heard that "Sigfox Technology is designed for low throughput IoT applications"?
Do you know *how low* exactly? And if your needs are different, should you look elsewhere?

Absolutely not, in fact there are many good reasons for using Sigfox Technology!

Fact: there is nothing to rival Sigfox energy efficiency for throughput under 1kB/day - this is what our study of protocol overhead vs. payload data volume reveals, as illustrated in figure 2.

BUT: your application is welcome to use more throughput, and this is likely to be the case if you're interested in specific Sigfox UNB benefits, such as deep indoor penetration or interference resistance ability.

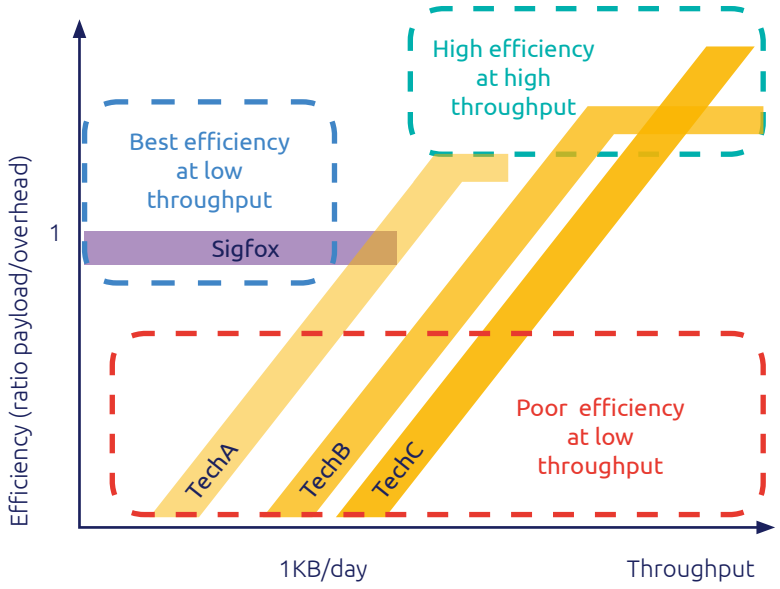

Figure 2: Big picture on energy efficiency vs. throughput

2.3 Data plan

A device subscription includes a communication data plan for a given maximal throughput per device (e.g. 2 messages per day). Additional communication over and above the data plan is delivered by the network as overage.

Bear in mind that you are liable for regulation conformance: remaining within a data plan ensures conformance, any additional communication is your own responsibility and must be kept within regulatory limits.

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2.4 Regulation conformance constraints for traffic models

Sigfox has strategically chosen to offer connectivity over unlicensed bands, which is why regulatory constraints apply to devices traffic model:

- In Europe (RC1), a 1% hourly duty cycle constraint applies for devices (ETSI EN 300 220), resulting in a maximum number of messages per hour.
- In the Americas and most Asia-Pacific countries (RC2/RC4), Frequency Hopping constraints apply (FCC Part 15.247), resulting in indirect timing constraints.
- In Japan and Korea (RC3/RC5), Listen Before Talk (LBT) timing constraints apply (STD-T108 for Japan and Radio Waves Act for Korea).

Timing constraints

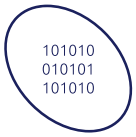
In practice, Frequency Hopping in RC2/4 imposes constraints on inter-message timings for bulk transmissions. For example, for RC2/4 *multiframe* transmission, a 10-second inter-transmission delay is currently recommended. Timing management can be handled by the Sigfox protocol library (request this at library init).

Maximum throughput

Device *maximum* uplink throughput is RC-dependent and derives directly from unlicensed spectrum regulation and transmission parameters - payload size, periodicity and frame replication (this parameter is detailed further in section 3). In practice, maximum throughput is never a concern outside RC1, which has the most restrictive constraint (1% duty cycle). E.g. a European device reporting 3-byte payloads can send 8 *multiframe* transmissions per hour (0.1% x 3600/1.45/3) and they can all be consecutive. The same device in the US can send more, with a constraint of a 10-second delay between transmissions.

2.5 Traffic model recipes

Now you know the ingredients and constraints, let's cook a good traffic model for your use case!



Methodology recipe - Start by categorizing the information to be reported over Sigfox, by size and criticity.

- Critical/mandatory data: triggers an immediate report (such as alarm, etc.), and cannot be delayed.
- Mandatory data with a low criticity level: no immediate report is required, the data can be delayed and aggregated with the next critical transmission.
- Nice to have: low-priority data is kept for opportunistic padding when space is available in a transmission container.

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Data categorization is the basis for applicative payload aggregation.

Slimming recipe #1 - Reduce your energy budget with applicative data aggregation

- Aggregate information of different types in a single payload. This avoids multiple transmissions. Remember: a single 12-byte transmission is more efficient than three 4-byte transmissions; it conveys the same amount of user payload using half the energy.
- ...but there's no reason to go for 12 bytes every time if it's not needed!
- The ideal payload aggregate length is 1, 4, 8 or 12 bytes. This avoids protocol padding and maximizes energy efficiency.

Slimming recipe #2 - Shrink your energy budget with a practical payload compression approach:

- Strip critical data down to the smallest possible size.
- Think data compression: use a known algorithm or invent a custom compression algorithm.

Slimming recipe #3 - Need more? Then design an applicative encoding:

- Identify and rank device report types based on their criticity and periodicity.
- The most frequent reports require more attention: they are worth the effort of compression.
- When consecutive reports are identical, go for short «no change» notification messages; this avoids sending multiple long messages with the same data.
- When consecutive reports contain data with little change, go for a short notification message containing delta information only.
- ...and don't forget we're doing radio, so think how to recover from contingent packet loss by adding reconstruction methods.
- There are many possibilities...think up some of your own!

Day-to-day recipe for routine keepers - Sensors that report periodically based on timer timeout, typically between 1 report every 30 mins and 1 report per day:

- Favor payload data aggregation in 12-byte containers for infrequent reports.
- For frequent reports, favor the smallest possible payload.
- Avoid synchronous transmission scheduling (precise + predictive) for device population.

Seasonal recipe for hibernators - Waking up after a long idle time and hungry for throughput? Some devices that are silent most of time wake up for an asynchronous event and need to send a lot of reports - alarm, movement or condition change detection.

- In hibernation there is no minimal periodicity: transmissions can be sparse depending on application need. For service management purposes, a transmission of one heartbeat per day will suffice.
- Favor heartbeat and alarm messages with the smallest possible payload.
- Design the greedy phase to comply with regulatory limits, especially in RC1 where periodicity is constrained.

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2.6 Frequently asked questions

I'm using 12-byte payloads all the time, although I could work out a solution with 6. The subscription cost is the same anyway, so why does it matter?

You do have an energy budget to manage, and using 12 bytes when you only need 6 means you're wasting 20% of your energy. Can you afford to do that?

My subscription gives me access to 50 msgs/d. I really only need 12, but I'll keep 48 as a safety margin. You never know the radio conditions, do you?

It makes sense to design your traffic model with a safety margin, but plan for a reasonable margin based on application need and energy budget rather than one based on billing and data plan. Message «repetition» by application is costly in terms of the energy budget, so don't oversize too much for fear of the radio conditions; it's usually not necessary! It's best to try out different typical conditions for your device, which will give you an idea of whether you really need to take additional precautions or not

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?

Why is there a limitation of 140 msgs/day in the subscription data plan?

Sigfox currently offers subscription data plans in accordance with protocol efficiency. Additional communication is possible and must comply with the applicable regulatory limits.

?

My alarm use case is silent most of the time (just a daily heartbeat). Under alarm conditions, it occasionally requires 250 messages in a day, is this possible with Sigfox?

Yes, provided you select the right set of transmission parameters. In RC1, the duty cycle constraint applies, so you'll have choose a trade-off:

- in RC1 for multiframe transmission, 250 messages are only possible with a basic alarm (1-bit payload).

- in RC1 for single frame transmission, 250 mesages are possible whatever the payload length.

- in all other RCs, there is no regulatory constraint related to this data volume and you can adjust the transmission parameters based on your other constraints.

Note that overage in respect of 250 messages may have an impact on billing depending on your commercial terms.

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?

My use case is an alarm system that requires a bulk of 16 4-byte transmissions, and otherwise remains idle. Can I build it with Sigfox? How long does it take for the sequence?

Yes, you can build it with Sigfox. Several sets of parameters are possible:

- in RC1, with 16 x 4B transmissions with multiframe, the cycle contains 70 seconds of emissions, which lasts more than 1hr with regard to the hourly Duty Cycle rule.

- shortening the cycle time is possible by aggregating payload data into 12-byte transmissions (again with multiframe). This enables the cycle to collapse to less than one minute if required (with 36 seconds for emission).

- shortening the cycle time by using single-frame transmission is also possible, although cycle duration gain is small in this case (also less than a minute) and there are potential side effects depending on radio conditions. For higher throughput, single-frame for bulk transmission cycle reduction is an interesting option.

- In RC2/RC4, 20 x 4 byte transmissions take less than 4 minutes in all cases.

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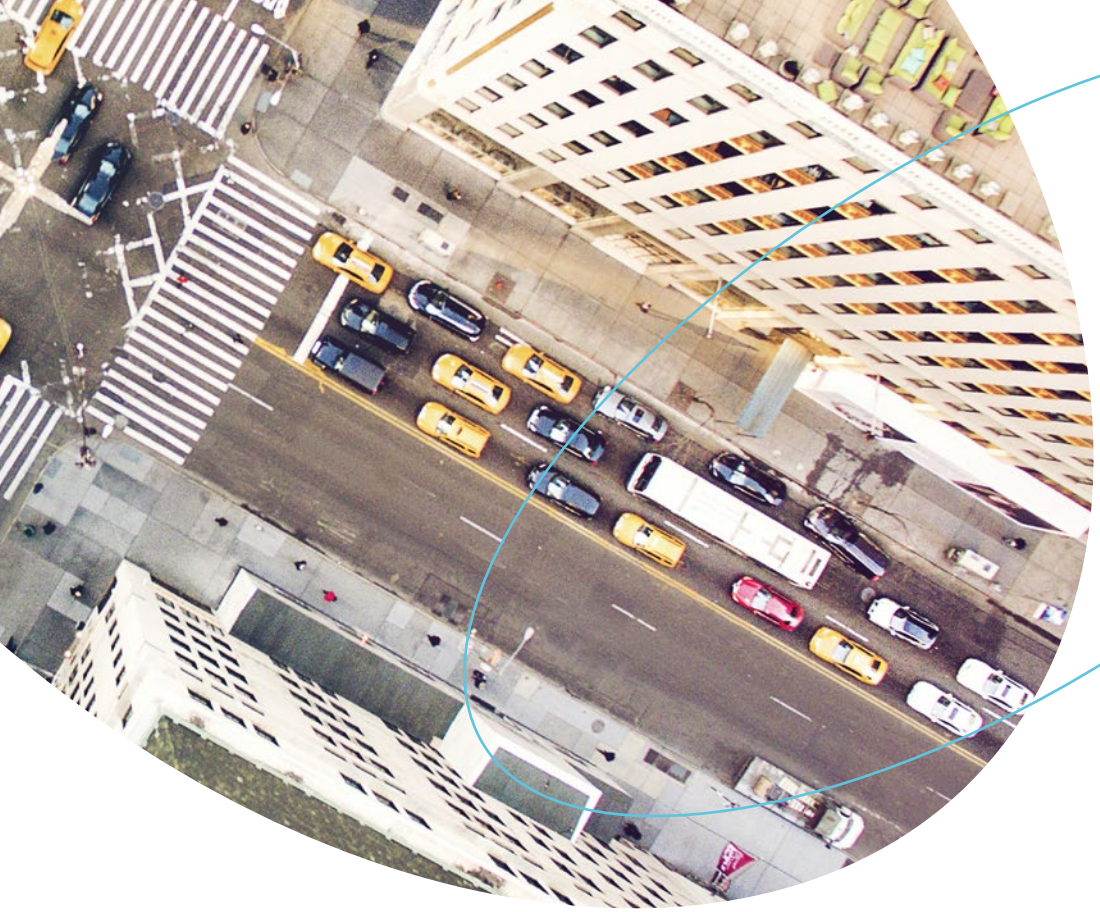

3 Replication, energy budget and use case

Shared spectrum challenges: a simple road traffic comparison

You take your car out on public roads every day and risk having an accident. The risk is reduced where there is compliance with traffic regulations, which is why new regulations are brought in all the time, and why you have to obtain a driving license. The risk increases with traffic density, and also with users of different types and temperaments - pedestrians have slim chance of survival if they cross a motorway heavily used by cars, trucks and trailers! Dedicated lanes ensure speedier progress and minimize risk, but cost a lot of money to build and require constant monitoring to prevent abuse. Only smart users, like nippy motorbikes, can make their way quickly through traffic congestion.

It's the same story with telecoms: random transmission over a pooled resource is by nature hazardous - more traffic, no regulations and different systems means more collisions and less chance of survival. Asynchronous resource access, modeled in the 1960s as ALOHA networking, is known to result in a rapidly decreasing quality of service as the number of users increases. Constant access control over a licensed spectrum certainly offers a solution, but it costs a lot of money to build and monitor. That's why Sigfox has designed a totally different solution.

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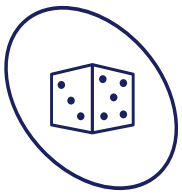
3.1 Understanding Sigfox triple diversity factors

Classical wireless systems *tightly discipline* their devices to minimize collision and packet loss. Tight discipline requires link control. Remember figure 2 in §2.2? Link control means more communication overhead and lower energy efficiency...not really suitable for small, infrequent IoT transmissions!

To promote the emergence of simplistic, energy-efficient IoT devices, Sigfox has engineered a unique radio access technology. **How?** Instead of robustifying the link with discipline, a virtual multipoint communication is obtained with diversity, virtually multiplying link success probability!



Having a hard time understanding diversity benefit? Statistically, it has the same effect as flipping a coin! Each flip gives you a 50% chance of scoring a head, but more flips give a greater chance of succeeding at least once. 2 flips give you a 75% chance of scoring a head, 3 flips give you an 87.5% chance...and with 7 flips your chance is greater than 99%! This is exactly how diversity maximizes Quality of Service - by pure statistical combination.

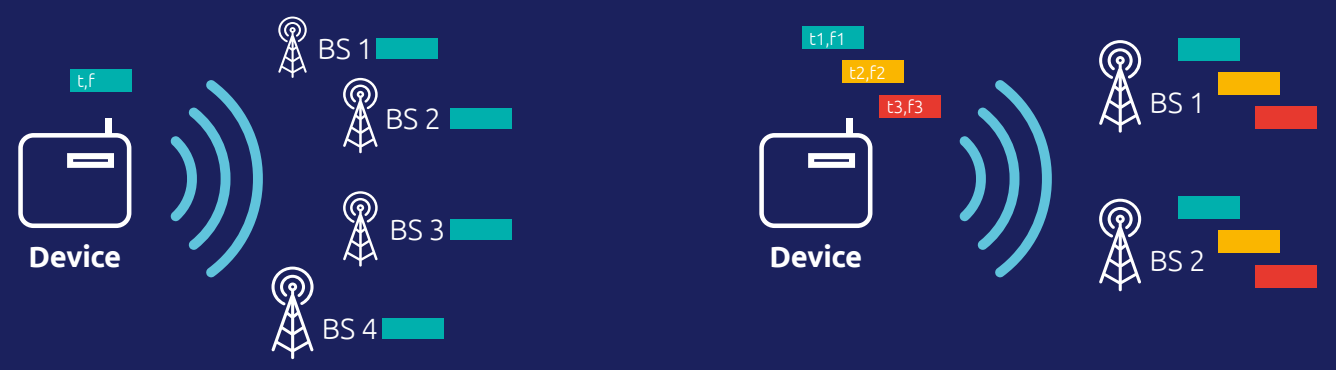
Back to telecoms with our virtual multipoint connection obtained with several virtual links (the equivalent of coin flips), via multi-dimensional diversity:

- frequency diversity, provided by random frequency selection for each device transmission;massive spatial diversity, provided by large array overlap in network deployments;
- optional time diversity with device-generated multiple frames, illustrated on the right-hand side of figure 2, consists of a device generating 3 distinct radio bursts (same payload, different frequency and coding).

Time diversity is a device contribution and spatial diversity is a network contribution. Although both diversity contributions have different leverage and slightly different benefits, it can be considered that a global diversity factor is important for quality of service. In practice, this means that when spatial diversity is high, the global diversity factor is already high, so time diversity is not needed and the device can dispense with multiframe and rely on single frame transmission. On the other hand, in situations where the network is sparse and spatial diversity low, multiframe transmission ensures a good diversity factor.

What is the global diversity factor?

The global diversity factor is simply the number of effective receptions in the network for a given transmission, as illustrated in figure 2. The higher the global diversity factor, the higher the quality of service.



Single frame received by 4 BS (diversity factor = 4)

Multiframe received by 2 BS (diversity factor = 3x2=6)

Figure 2: global diversity factor illustration with single frame (left) or multiframe (right)

3.2 Time diversity: constraints and benefits

Quality of Service

In fact, if you dig a little further, time diversity is a *correlated* diversity factor: multiple frames are generated within a limited time interval (no longer random), which somehow limits the statistical benefit of time diversity. This effect, combined with the multiframe contribution to network loading, results in a smaller QoS benefit than the equivalent spatial «macro» diversity.

This is illustrated in figure 3, representing the 2D ALOHA model of QoS as a function of network load in static conditions with time diversity or spatial diversity: the benefit at low resource load is similar, but spatial diversity proves superior in loaded conditions.

Of course, this is only true where there is equivalent radio link quality, and is slightly tempered when you're looking at a variety of radio situations. Just remember that in good radio conditions, spatial diversity is more *powerful* than time diversity.

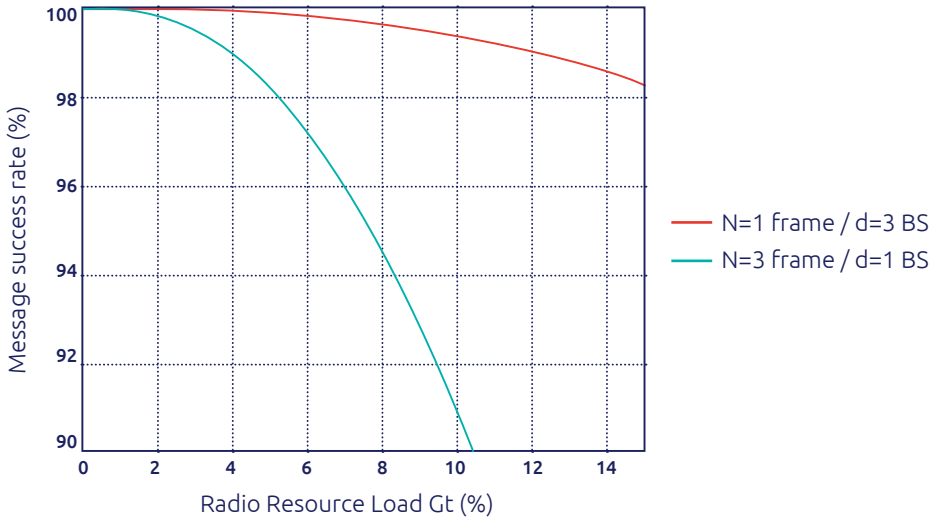


Figure 3 - Quality of service expectancy for a total diversity factor of 3, with time diversity or spatial diversity as single diversity factor.

Energy budget

Single-frame transmission offers simple implementation for an attractive energy budget and longer battery life, and means that smaller, cheaper batteries can be used. With time diversity transmission, the energy budget related to the transmission phase is multiplied by the time diversity factor (x3).

Mobility conditions

Multipath propagation due to device mobility conditions applies significant distortion on the transmission waveform, resulting in a potential transport success rate hazard. Diversity is useful again for a Quality of Service experience. Spatial diversity in mobility is of primary importance though, and time diversity acts as a complementary mechanism.

Bulk transmissions

Unavailability of a device modem function due to active transmission depends on the transmission duration. Single-frame transmission duration is about one third that of multiframe: modem unavailability is notably decreased (reduced to a 3rd), and the data refresh rate is tripled, which is convenient for bulk message transmissions.

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3.3 Operation on single or multiframe

Single or multiframe capability is built in the Sigfox library and configurable via the library API. The transmission option, whether single or multiframe, is selected by the application firmware.

Depending on the design of the application firmware, selection can be statically hard-coded or dynamic. Dynamic selection can be performed on a per-message basis for pure applicative consideration (depending on the data value, for example), or based on a radio link quality estimation, in which case the replication scheme is said to be adaptive.

How do you implement an adaptive scheme? A device application can initiate a downlink cycle for communication control purposes. When the remote customer server replies with error rates and current quality of service, the device can resend missing information and eventually adapt its operating parameters (switching between replication and single frame).

Note: a single frame transmission is identical to the first frame of a multiframe transmission. There is no protocol marker, so the network doesn't know if a transmission is performed in single or multiframe in the event that only a first frame is received. But it doesn't really matter because only one reception is necessary for transmission success!

3.4 Recipes for frame replication

In the great majority of situations, Sigfox devices using multiframe schemes are perceived by the network with all replicas, meaning that the equivalent service is offered with a single frame, and with a more attractive energy budget. Frame replication remains useful for a fraction of use cases, in which a consistent portion of frames is lost. What should you select then, and when? This section provides simple recipes to find the right way for your particular use case.

Methodology recipe

Start by identifying and ranking the constraints applied to your use case:

Energy

Is the energy budget the dominant constraint?
Is battery size/cost/ lifetime critical for my use case positioning?

Radio link quality

Will devices be in good/poor radio conditions?
Are they outdoors? Urban? Rural? Indoor? In industrial locations? Mobile?

Periodicity

What is the periodicity of my device reports?

QoS

What is the criticity of the reported transmissions?
Can I tolerate some level of error?

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When you have a clear view of your dominant constraint(s) and acceptable compromises, proceed with the cooking recipes!

Cooking with single frame transmission

- Single frame transmission is the natural operating mode for use cases with a strong energy saving motivation and/or long-term battery operation.

- Single frame transmission is best suited to use cases operating in good radio conditions (cf. Table 3), as service quality impact is in this case marginal: link stability and spatial diversity neutralizes the absence of time diversity.

- Single frame transmission is best suited to use cases with high transmission periodicity. Simple applicative encoding mechanisms allow history recovery and compensate the single frame potential QoS impact.

Cooking with frame replication

- Multiframe transmission is best suited to use cases operating in hardened radio conditions: the time diversity brings a quality of service complement, at the cost of an additional energy budget. Hardened radio conditions notably encompass use cases with low spatial diversity and weak signals, either because of the device's intrinsic performance (device class 2 or 3), or because of its location (rural, deeply buried, coverage fringes, etc.). Table 2 summarizes how to determine which option to use, based on the observed Link Quality Indicator (LQI).

	Link Quality Indicator	Single or multiframe?
	1 (limit)	Multiframe
	2 (average)	Multiframe
	3 (good)	Single frame
	4 (excellent)	Single frame

Table 2 - How to select single or multiframe based on observed radio link quality.

Mobility

Mobility is considered a hardened radio condition, but the choice of single or multiframe is not necessarily obvious:

- Infrequent GPS-aided tracking is a candidate for multiframe for its QoS benefit,

- For tracking/alerting with series of transmissions, the alerting duration is key and favors single frame implementation for its energy saving benefit. With single frame, each radio burst contains the latest available information, which can also be of interest.

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3.5 Single or multiframe for my use case?

Because a few practical examples provide a better understanding than long generic recommendations, here is a practical ranking table:

DOMINANT CONSTRAINT		REPLICATION SCHEME			Comment
		Single frame	Multiframe	Adaptive scheme	
POWER	Grid powered	+	++	o	Grid powered devices are not subject to energy constraints and can implement any necessary mechanism
	Battery powered	++	+	+	Energy constraints favor single-frame implementation (unless a stronger constraint applies)
	Energy harvesting	++	o	o	Occasional applicative checks are a better trade-off than replication, in terms of the energy budget
PERIODICITY	Asynchronous alarm bulk transmissions	++	o	o	Bulk transmission flow is faster in single frame
	Infrequent periodic reports (≤5 per day)	+	++	+	Periodic link quality checks can serve to adapt replication & periodicity
	Frequent periodic reports (>5 per day)	++	o	o	Frequent periodic reporting can be robustified by applicative protocol implementation (e.g. with current & delta encoding §2.6)
DATA	Critical payload data	o	++	o	Critical data is worth a conservative QoS approach and related energy budget, if necessary
	Commodity payload data				Commodity data is allocated minimal energy budget
RADIO LINK	Good or very good radio link (outdoor, urban, roof, etc.)	++	o	o	Good radio link conditions offer QoS. Replication scheme unnecessary
	Average or limited radio link (rural, ground level, underground, buried)	++	o	o	In limited radio link conditions and sparse network perception, replication scheme complement is welcome.
	Unknown link condition	o	++	o	Both static configurations are possible and the decision is based on other use case criteria. Adaptive replication scheme is recommended, for example at commissioning.
	Mobile tracking/ alarm with bulk messages	++	o	o	Tracking based on bulk messages can be no different to single message reception rate, especially when the alerting period length is essential. Single frame can also be a good trade-off due to refresh rate increase.
	Mobile device/ reporting	+	++	o	Infrequent reporting in changing conditions may require a conservative approach

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3.6 Frequently asked questions

Every use case is different and many details are not covered in the generic recommendations above. Here's a favorite selection!

How do I choose between single and replicated frames for operation?

Based on your use case mostly: when energy is a constraint, when radio link is good or when refresh rate matters, go for single-frame static operation. For critical data, extremely infrequent transmissions or limited radio link conditions, go for multiframe. For general purpose devices, the choice depends on the type of product and data criticity; an automatic configuration procedure at commissioning is a reasonable option to detect and adapt the replication scheme.

Is there a risk in migration to single-frame service for my devices?

It clearly depends on your application specificity. For the majority of devices, the link quality is good (outdoor, urban, roof and upper floor level situations) and the migration risk marginal. In this case, the single-frame service offers the best long-term performance/energy trade-off.

However, if your application is operated exclusively in hardened radio conditions, (deep indoor, mobility), consider multiframe transmission or at least adaptive mechanisms.

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I am in smart city business and I offer a wide range of solutions: parking sensors, air pollution detection, smart lighting, noise measurement, intrusion detection and water metering, among others. Is single frame suitable for all of them?

Some of your solutions clearly benefit from good radio conditions in urban areas (air pollution, noise detection, smart lighting) because they are outside, in elevated situations above ground. For these, the single-frame service is a good low-risk choice.

Parking sensors and metering are subject to more variability in radio link quality due to large signal loss, dependent on installation conditions. These are typical applications where multiframe time diversity is beneficial.

Does Sigfox provide the adaptive mechanism for replica selection depending on observed quality of service?

The Sigfox protocol library does not provide adaptive implementation. The protocol library just executes the desired replica scheme for the next transmission. The adaptive scheme must be implemented in the device application. This is quite simple and may consist of a simple link quality check performed opportunistically during a duplex sequence.

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I designed a device a year ago, using a multiframe scheme. How can I upgrade to single frame service.

First, make sure you have a Sigfox library which provides access to the replica configuration API - the feature is available from V2.5.0 onwards. If you are a modem maker with an earlier version, simply go to build.Sigfox.com to request the latest library. If you buy a packaged solution such as a module, request a firmware update with the Sigfox compatible lib. Build your implementation, test it and request verification!

If I understand correctly, replication is leveraging quality of service. So why not 2 or 5 or 10 replicas?

Sigfox protocol configurability with single (1) or replicated (3) frame(s) serves 99% of use cases. Situations where additional protection is required are rare, however if you feel it is necessary for yours, you can implement additional applicative message re-transmission.

I subscribed to the silver data plan with 50msg/d for devices using the multiframe scheme, which is technically 150 frm. Can I go up to 150 msg/d with the single frame service?

Yes, but not within 50msg/d dataplan! subscription is contracted for a given data throughput expressed in messages per day independently of single or multiframe. Communication above the subscribed throughput is possible, subject to specific commercial terms.

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My application goes into good radio conditions. Isn't it more advantageous to apply for class 2 with replication than class 0 in single frame?

No. Both system trade-offs result in similar energy savings and potentially leverage on Quality of Service. However, class reduction reduces LQI (range and spatial diversity), while single frame withdraws time diversity at equivalent LQI.
In other words, if your conditions are exceptionally good, go for Class 2 single-frame implementation, otherwise go for single-frame class 0 as it preserves LQI and spatial diversity - the most powerful diversity factor.

I have built a dynamic replica selection within my device. I'm experiencing message loss, what's going on?

The single frame implementation alone cannot explain a drastic message loss experience in equivalent radio conditions. First, check the link quality indicator for your device. Is it stable? Both before and after the firmware change? Is LQI severely degraded? If there are significant changes in link quality, then the message loss is not due to the single-frame service and is most probably due to some other parameter change, e.g. device condition changes (antenna connection, device placement, etc). For further investigation, call in at your local support centre.

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4 Matching use case and device class

There are potentially infinite ways to combine use case operating conditions with device class. There are even options to get substantial energy savings when adjusting power based on experienced operating conditions. There's a lot to say, but for now, let's start with the simplest ingredients and a small set of basic recipes!

4.1 Ingredients

Device class

At device system definition you select a target radiated power, which is a major ingredient in the communication configuration. From this system requirement, which is usually quite challenging, your hardware guys try out the best implementation by integrating the transmitter on the PCB with antenna and casing, optimizing it for best radiated performance and minimal energy loss, etc. When it's ready, your product applies for certification and undergoes a *device class assessment*. The association of class/radiated power is explained briefly in Table 3. You can check for more detailed information on device classes on Sigfox web resources.

Why does a device's radiated power matter? Because the quality of the link between an object and the network is never a network-only concern! In fact, in identical network conditions, devices radiating different power do not experience the same service. Note in Table 3 that class boundaries are separated by 5dB. This corresponds roughly to a device «reach» reduction of 25% between one class and the next, as illustrated in Figure 4. Your device class assessment is done in anechoic chamber conditions: these canonical conditions are different from your device operating conditions. From this perspective, the assessment provides a sanity baseline more than a guarantee of field performance.

Why is this important? Field performance is related to how well your device (antenna) is designed for its target operating conditions. Specifically, devices that are wall-mounted, hand-held by humans or buried in the ground require specific attention for optimizing performance. You will find more information on optimization in the antenna section of **build.Sigfox.com**

Remember that assessing your device performance in various situations corresponding to its target operating conditions is highly advisable. Device class certification alone is a minimum requirement, but it is not sufficient to ensure good performance in the field.

Device Class	Device EIRP		
	RC1, RC3	RC2, RC4	RC5
0	>=12 dBm	>=20 dBm	>=10 dBm
1	>=7 and <12 dBm	>=15 and <20 dBm	>=5 and <10 dBm
2	>=2 and <7 dBm	>=10 and <15 dBm	>=0 and <5 dBm
3	< 2 dBm	< 10 dBm	< 0 dBm

Table 3 - Sigfox Device Class characteristics

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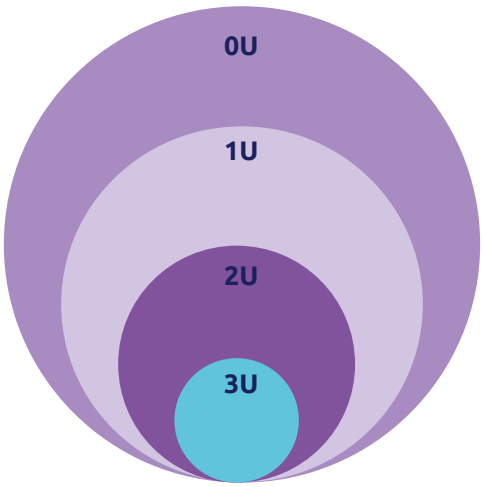

Figure 4 - Big picture on relative device footprint vs. class

Device power adjustment

For most use cases, radiated power is intended to be static over the device operating life. Specific use cases will take smart benefit of a custom energy budget by implementing from an applicative power adjustment mechanism. This is of course an advanced feature, so don't go for it unless you are strongly motivated and are equipped with RF testing equipment! Also, take good care of your radiated spectrum template!

4.2 Losses due to device operating conditions

There's a lot of literature on indoor penetration losses. Please bear with us, more details will follow in the next edition!

4.3 Survival recipes

Cooking with higher class

Higher class is an interesting option for use cases operating in good/exposed radio conditions such as urban outdoor rooftops or high-level floor locations, because link quality and stability is highly favorable and a portion of the very high link budget can be used to save energy and extend the lifetime of the battery or use one of lower capacity (size & cost).

Higher class trade-off is also an interesting solution for use cases with a strong energy saving motivation. Of course, you have to pick the right target for your application regarding link quality in operation in order to get sufficient coverage!

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Cooking with Class 0

Class 0 is well-suited to use cases operating in unknown or hardened radio conditions. Hardened radio conditions in particular include use cases with low spatial diversity and weak signals, either because of the device's intrinsic performance or due to the location of the device (rural, deeply buried, coverage fringes, etc.). Table 4 provides a summary on how to decide which option to use, based on the observed Link Quality Indicator (LQI).

	Link Quality Indicator	Class target
	1 (limit)	Class 0
	2 (average)	Class 0 or 1
	3 (good)	Class 1 or 2
	4 (excellent)	Class 2 and +

Table 4 - How to select a class target based on observed radio link quality.

Mobility is considered a hardened radio condition with a high level of unpredictability. In this case, a conservative class 0 approach is recommended.

4.4 Which class for my device?

DOMINANT CONSTRAINT		DEVICE CLASS				Adaptive power scheme	Comment
		0	1	2	3		
POWER	Grid powered	+	+	+	+	O	Grid powered devices are not subject to energy constraints and can implement any required device class.
	Battery powered	+	++	+	+	+	Energy constraints are favorable to "high" class implementation (unless a stronger constraint applies)
	Energy harvesting	+	+	++	++	O	Occasional applicative checks are a better trade-off than replication, in terms of the energy budget
RADIO LINK	Good or very good radio link (outdoor, urban, roof, etc.)	O	+	++	++	+	Good radio link conditions offer QoS. The more exposed the radio conditions, the higher the class possible, the lower the EIRP and the higher the energy savings!
	Average or limited radio link (rural, ground level, underground, buried)	++	+	O	O	O	In limited radio link conditions and sparse network perception, conservative class selection is recommended, with efficient antenna design to optimize energy efficiency.
	Unknown link condition	++	++	O	O	+	Be conservative and target for Class 0. Planning for adaptive power is reasonable and will increase the autonomy of your device.
	Mobile tracking/ alarm with bulk messages	++	++	O	O	O	Mobile involves unpredictable radio conditions by definition, so the conservative approch applies. Aaptive scheme is not recommended.

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4.5 Frequently asked question

Is there an automatic network-managed power adjustment available?

No. Unlike telephony, there is no “one-size-fits-all” in IoT - each IoT use case is different and has its own set of system constraints. Sigfox transmission protocol is designed to match the GCD of all use cases. Automatic, network managed, power control implementation draws intrusive system impact, and as such is certainly not part of the IoT GCD. A custom device-managed implementation remains more efficient for that matter: it meets the use case requirement with a perfectly-suited system trade-off.

My application goes into good radio conditions. Shall I target class 2 with multi frame or class 0 with single frame?

Both system trade-offs result in similar energy savings and potentially leverage on Quality of Service. However, power reduction reduces LQI (range and spatial diversity), while single frame withdraws time diversity at equivalent LQI.

In other words, if your conditions are exceptionally good, go for Class 2 single-frame implementation, otherwise go for single-frame class 0 as it preserves LQI and spatial diversity - the most powerful diversity factor.

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5 Data downloading

The Sigfox download service is available for device applicative purposes. A download sequence is always device-initiated via a device transmission - the application firmware indicates explicitly that a response is expected. The response content is provided by the application server.

Although recommended, a receiver implementation inside a device is not mandatory; Sigfox protocol does not require access to the receiver for link control purpose. When download is not mandatory for applicative purposes, devices can operate in transmission only throughout their operational life, without activating the receiver or without a receiver.

Note specifically that Sigfox protocol does not explicitly acknowledge reception of a device transmission; dedicated engineering based on diversity ensures Quality of Service, as detailed in §2.1. For use cases with highly specific constraints related to information transport, an applicative acknowledgement can of course be implemented.

Note: download service implementation recommendations are provided in a dedicated application note.

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