Application of Multi-network (Roaming) SIMs for 4G Backhaul in LoRaWAN Gateways

Multi-network (aka roaming) Subscriber Identity Modules (SIMs) have often been proposed as the solution to intermittent or unreliable Global System for Mobile Communications (GSM), communications, but this is only half the story – a story rarely understood or fully explained by those selling such products.

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Introduction

In this article, we explore the technical and commercial considerations of using multi-network SIMs to make backhaul from cellular-based long range (LoRa) gateways more reliable than when a single network SIM is used (Figure 1).

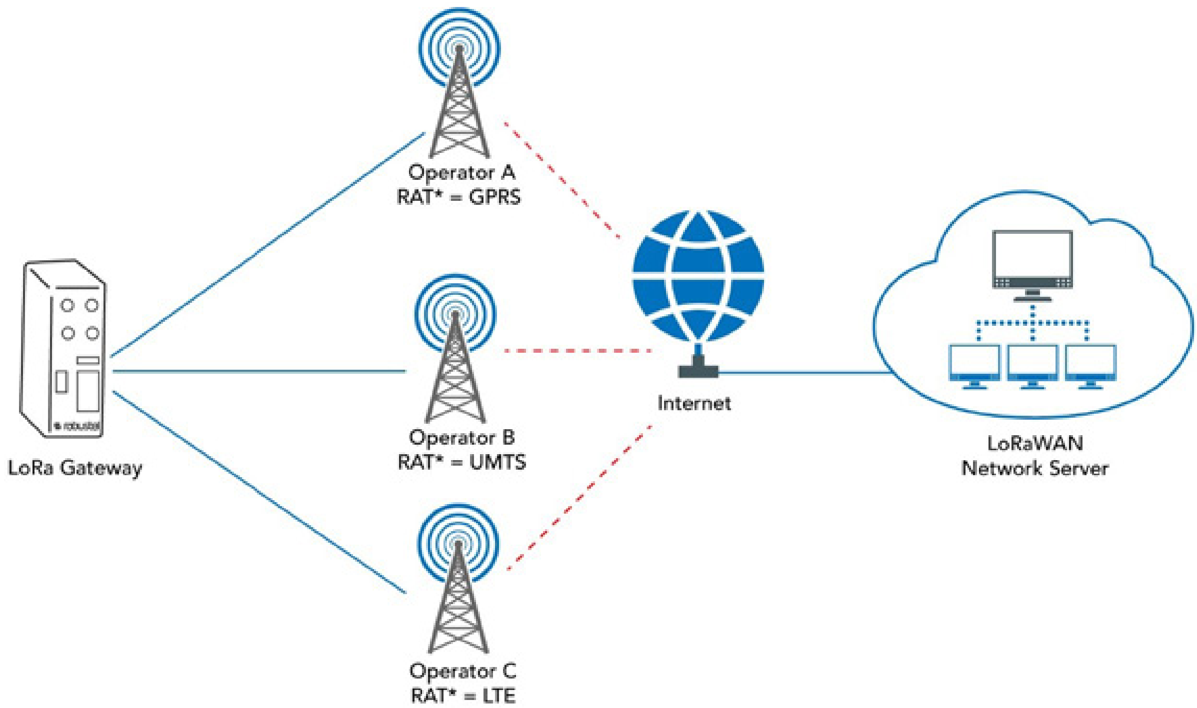

Figure 1: Using a roaming SIM provides diverse routes to the internet giving a higher chance of successful communications between Gateway and Server

SIM types

To fully understand the options, we open with an overview of fundamental SIM types that can be used in a long-range Wide Area Network (LoRaWAN) gateway.

1) Single Network

Single network SIMs cover a single network, typically in a single country. If no coverage exists on a particular network at an installation location, especially if it is in a building, then the communications will not work. And if the deployment is multinational, then it becomes necessary to maintain lots of different SIM agreements for different territories, which is logistically difficult and virtually impossible to manage at scale.

Roaming or multi-network SIMs, such as those from aggregators KPN, Vodafone GDSP, Tele2, Telenor, and their value-added reseller partners, have been the traditional solution proposed to the problems just mentioned. What most people don't realize is that not all roaming SIM cards are equal.

2) Steered Roaming SIM

This type of SIM can in theory access multiple networks per country, but in practice will favor a specific network or subset of networks for the mobile operator's commercial benefit. Usually steering is not implemented for the benefit of reliable communications but to make the scheme less costly by using only preferred networks. But this use of preferred networks results in the opposite of what IoT service/system providers who need as close to 100% network uptime as possible want, because the favored network may be unable to deliver a service when a non-favored one can!

While steered roaming is a complex subject just touched on here, one solution is to select a good quality unsteered roaming SIM provider to remove the vagaries of steering from the application.

3) Unsteered Roaming SIM

As the downsides of steered roaming have become more visible in the market, certain mobile network providers have started to provide and champion unsteered roaming SIMs. This means the SIM has no preferred network list onboard and does not suffer operator steering at the network level. Essentially, an unsteered roaming SIM is a blank canvas that simply provides access to networks as and when required with no 'loading of the dice.'

Having established a source of a good quality unsteered roaming SIMs, we can then investigate how a LoRa gateway reacts to such a SIM and other measures to optimize gateway-to-server communications reliability .

Network selection process

One of the most misunderstood concepts surrounding roaming SIMs is that of network selection.

Contrary to what many people have been told, SIMs do not play an active part in network selection (USIM toolkit applications excepted). Choosing an appropriate network is a function of the hardware, not the SIM card.

LoRa gateways are built using off-the-shelf cellular (typically 4G LTE) modules such as those manufactured by Telit, Gemalto, Quectel, Huawei, and other companies.

The module takes care of all interaction with the mobile network from the RF layer upwards. Most modules have a TCP/IP stack onboard for simplified application development but can also act in a modem mode, whereby the TCP/IP stack in the host system (typically Linux for a LoRa gateway) acts as the IP endpoint for gateway/server communications.

The host system communicates with a cellular module using industry standard attention (AT) commands, as defined in GSM07.07 and GSM07.05, as well as a range of (module) manufacturer-specific AT commands.

These commands determine how the module in a LoRa Gateway should behave, and a subset of AT commands are directly associated with the network selection process.

The vast majority of LoRa gateway manufacturers will use automatic network selection by issuing "AT+COPS=0" to the module, which instructs the module to take care of registering to a network per the set of rules in TS 3GPP 23.122 as detailed below:

"The MS (cellular device i.e. LoRa Gateway) selects and attempts registration on other PLMN/access technology combinations, if available and allowable, in the following order:

i. either the HPLMN (if the EHPLMN list is not present or is empty) or the highest priority EHPLMN that is available (if the EHPLMN list is present);
ii. each PLMN/access technology combination in the 'User Controlled PLMN Selector with Access Technology' data file in the SIM (in priority order);
iii. each PLMN/access technology combination in the 'Operator Controlled PLMN Selector with Access Technology' data file in the SIM (in priority order);
iv. other PLMN/access technology combinations with received high quality signal in random order;
v. other PLMN/access technology combinations in order of decreasing signal quality."

To aid with understanding of the automatic network selection process, please see the Glossary of Terms in Table 1.

PLMN = Public Land Mobile Network = Mobile network
HPLMN = Home Public Land Mobile Network = Home network
EHPLMN = Effective Public Land Mobile Network = Network with effective status of Home network
Access Technology = Radio Access Technology such as GPRS/UMTS/LTE approximating to 2G/3G/4G

It's important to note that the automatic network selection process does not make mention of the "last known good network" paradigm, whereby knowledge of previous successful registration to a network is stored in the SIM. This paradigm will take precedence and means a SIM will attach to the previous network, irrespective of a change in location or change in network conditions, so long as basic criteria are met.

When using an unsteered SIM without a notification of a previously registered network, none of conditions i to iii above are met, meaning that the module will take action iv as the first step in automatic network selection.

Action v entails the module performing a network scan to identify local networks and associated technology (GPRS/UMTS etc.).

Once complete, the module will ascertain which networks have a good quality signal and choose at random the network where it will attempt registration first, selecting from among all good quality networks.

The key term here is at random.

Many people peddle the 'strongest signal' myth, suggesting that a roaming SIM will always go to the 'strongest signal' first. As can be seen from the TS 3GPP 23.122 specification discussed earlier, registration on the strongest signal will only be attempted in step v if there is no possibility to register to a network using the methodology described in step iv.

If one imagines 200 people disembarking from an airplane at a holiday destination and switching their phones on at roughly the same time, it is quite evident why a random and distributed sharing of the roaming traffic is desirable, hence the fundamental design of the automatic network selection process. (The roaming process was originally invented for consumer handsets, not LoRa gateways!)

The problem with automatic network selection

Now that the process of automatic network selection is understood, it's easy to discover its limitation. Automatic selection only uses signal strength to determine a usable network, but a low-level received signal strength indicator (RSSI) measurement is by no means definitive proof that the chosen network can support end-to-end IP based communications. So, we need something else, something that will supplement automatic network selection to make sure we are getting the best service available.

Commercial considerations of roaming / multi-network SIMs

Having ascertained that a roaming SIM will likely give a better “uptime” for an estate of LoRaWAN gateways, it is essential to consider the financial implications of a move from single network to roaming SIMs.

Until recently, roaming SIMs have only been commercially viable for very low data usage applications such as vehicle tracking and smart metering—especially when considering an unsteered roaming SIM, where any network can be freely visited without limitation.

However, changes in the market now mean that on some continents, roaming is now very affordable, and the EU is certainly leading the charge on this subject.

$10 to $20 per GB per month is now available in the EU for a good quality unsteered roaming service. Is it worth paying extra to get closer to 100% uptime across an estate of LoRa gateways? While the answer depends on the intended application, it’s important to know that those whose backhaul is depending entirely on cellular communications have a choice to receive better service and what they must do to capitalize on this choice.

It is this fundamental issue that Robustel’s SMART Roaming capability aims to solve, using the simplicity of automatic network selection but supplementing it with health-checks and the use of manual network selection to make sure reliability is as high as it can possibly be.

SMART Roaming – a solution to an age-old problem

Robustel’s LoRaWAN gateways support SMART Roaming, which can be configured to check for loss of mobile data communications on the current network and force a change to an alternative network within a short period of time. This can save the cost of site visits and provide peace of mind that the highest possible reliability cellular methodology is keeping the packet forwarder of the gateway in communication with the LoRaWAN network server.

SMART Roaming checks not only signal strength, but also ping times and ping completion to build a more complete picture of the current connection. If the health-check is failed, the router will dynamically assess the quality of alternative networks and change to the next best if communications are lost or are of a 'low quality.'

This fundamental concept is used to great effect in the metering market, where millions of devices are deployed, and an overall estate uptime of close to 100% is achieved as a consequence. This technology is generally developed and tuned for a specific cellular (2G/3G/4G) module and roaming SIM combination. Generalizing the solution for a multitude of networks is not easy, but that's what has been achieved in Robustel's LoRaWAN gateways courtesy of the SMART Roaming application.

Summary

The idea of being able to transmit data on multiple radio networks rather than depending on just one as a means of improving reliability has long been recognized. However, it is a complex subject matter that falls between the domain of the SIM provider and the hardware provider. Breaking down these knowledge barriers and providing an off-the-shelf SMART Roaming solution is Robustel's contribution to helping with the proliferation of LoRaWAN as a standards-based and highly flexible LPWAN solution.