LORAWAN REGULATORY GUIDE REPORT

FOR DEPLOYMENT OF WEATHER STATIONS IN BUSIA

CONTENTS

EXECUTIVE SUMMARY

In recent implementations of Internet of Things (IoT), aspects of cost, scalability, coverage, and energy efficiency have become increasingly important in considering the suitability of what networking technology can be used in intelligently obtaining data from sensor nodes.

Earlier implementations of IoT were based on Bluetooth, Wi-Fi (for indoor applications) and cellular technologies (particularly GPRS for outdoor deployments) driven by the vision of IPv6 which guarantees a plethora of addresses to deploy massive IoT devices. However, as more IoT applications such as smart metering, wearable devices, remote monitoring for healthcare and other applications as well as industrial automation scale, there has been a gradual embrace of Low Power Wide Area Networks (LPWANs).

Low Power Wide Area Networks (LPWANs) are wireless networks designed to allow long-range communication at a low bit rate among battery-operated devices. Their low-power, low bit rate and their intended use distinguish these types of networks from the already existing wireless Wide Area Networks (WANs) – which are designed to connect more users and businesses and carry more data, using more power. Some of the examples of LPWANs include Narrowband IoT (NB-IoT), LTE-M, Long Range (LoRa) and Sigfox which connect edge devices situated outdoors in remote areas that have no available last-mile connectivity.

Among the LPWANs, NB-IoT and LTE-M are considered licensed versions due to their existence under the 3GPP standardisation operating as part of the LTE and 5G cellular infrastructure. On the other hand, SigFox and LoRa are seen as licence-exempt technologies operating in the Industrial Scientific and Medical (ISM) bands making use of 868 MHz (in ITU region 1) or 915/902 MHz (in ITU region 2). However, SigFox and LoRa differ in many forms in terms of the frequency bands used, channel width, range, standard transmit power as well as other parameters such as the data rate and topology.

In recent IoT developments, LoRa has become the leading licence-exempt LPWAN technology and is backed by various communities presently deploying massive IoT devices and evaluating regulatory requirements. Originally developed by Cycleo and acquired by Semtech, LoRa has tremendously grown within the LoRa Alliance to enable collaboration and shared experiences that promote and drive the success of LoRaWAN. LoRa Alliance is an open, non-profit association that contributes and supports the maturity and collaboration of the LoRaWAN standard.

It is within the LoRa Alliance framework that regulators are keen to observe, learn and develop fitting regulations and regulatory requirements based on different contexts and scenarios. However, regulatory engagements are not heavily addressed at the LoRa Alliance level and are left to be provided by the country regulators. In Kenya, the Communications Authority of Kenya (CA) supports provision of pre-deployment survey reports to help inform on the sites, transmission power requirements and the height of the antennas to be used among other factors. This is because the CA targets to make revisions to the published guidelines on the use of RF Spectrum by Short Range Devices (SRDs). Therefore, this report shares a pre-deployment regulatory guideline for the planned IoT deployment in the Busia County of Kenya.

ABOUT LORA AND LORAWAN

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ABOUT LORA & LORAWAN

LoRa is a long-range, low power, low bit rate and single-hop wireless communication technology. It is intended to be used in Internet of Things (IoT) applications involving battery-powered devices with low throughput requirements. LoRa uses a patented modulation developed by Semtech based on the chirp spread spectrum (CSS) modulation. LoRa can be used with public, private or hybrid networks to achieve a greater range than cellular networks.

Each bit of LoRa is spread by a chipping factor. The number of chips per bit is called the spreading factor (SF). CSS uses spreading factors from 7 to 12. Small spreading factors provide high data rates and require less over-the-air time. Large spreading factors provide low data rates and require more over-the-air time. LoRa modulation is more complex and resilient to background noise. It is suitable for building long-range communication channels with low data rates.

Long Range Wide Area Network (LoRaWAN) is the communication protocol and system architecture for the network. While the LoRa physical layer enables the long-range communication link, LoRaWAN has the capacity to have an effect on battery lifetime of the sensor node, network capacity, quality of service (QoS), security and applications served by the network. Since LoRaWAN consists of end nodes (or sensor and/or actuator devices), a network server and application servers, the LoRa gateways provide the telecommunications infrastructure for relaying data from the end nodes. In most scenarios of LoRaWAN, multiple gateways are installed to enable reception of data from the transceivers (implemented as part of the sensor nodes) to be forwarded as packets to the cloud. The forwarding of packets is done through the backhaul network of the gateway which can be cellular, ethernet, Wi-Fi or satellite. The software behind forwarding of packets is referred to as packet forwarder.

The distinction and architecture for both LoRa and LoRaWAN are shown in figure 1 and 2.

Technology	Stack
LoRaWAN®	Network Layers MAC Layer
LoRa	Physical Layer

Figure 1: Distinction between LoRa and LoRaWAN

LORA AND LORAWAN TRANSMISSION

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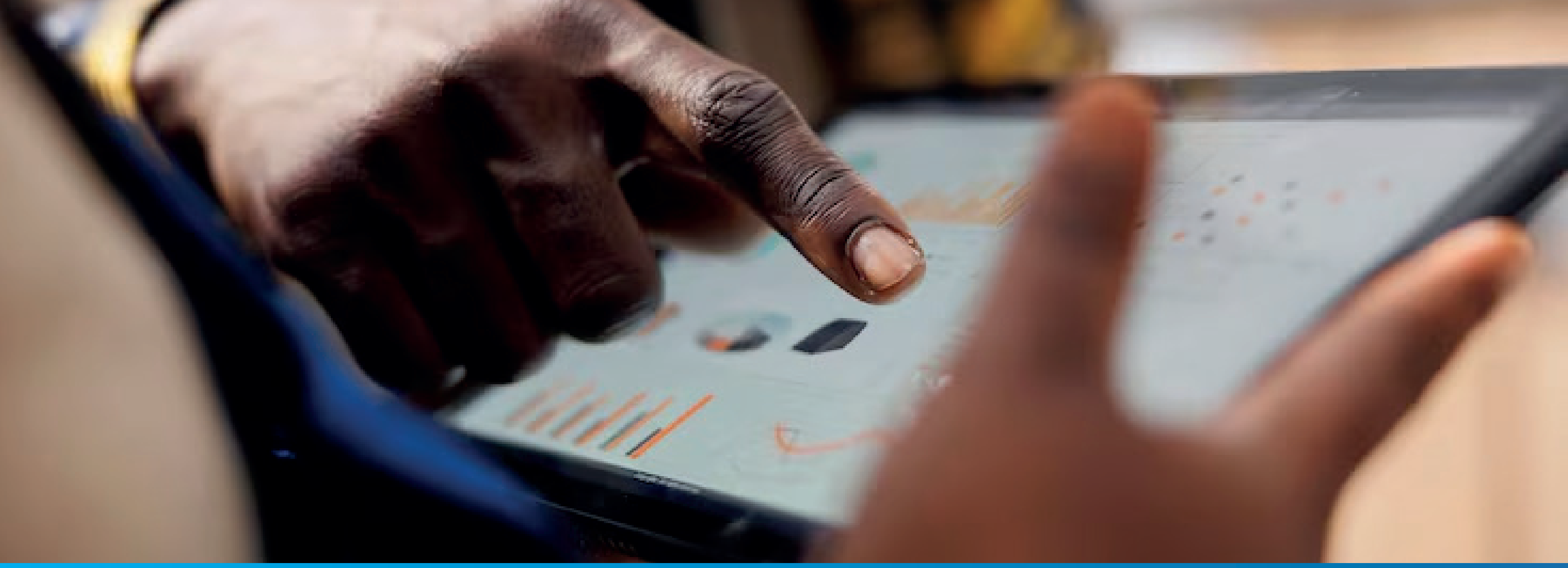

LoRa AND LoRaWAN TRANSMISSION

Each LoRa transmission is characterised by five parameters:

1. Spreading factor.
2. Transmission power
3. Coding rate.
4. Centre frequency.
5. Bandwidth.

These parameters affect the communication range, the data rate, the robustness to interference and noise and the ability to decode the signal. The available values for each parameter depend on the region where LoRa devices are deployed.

LoRaWAN relies on an ALOHA-based MAC protocol, which reduces the complexity of end devices. The end devices do not need to peer with specific gateways. Messages sent from end devices travel through all gateways within range.

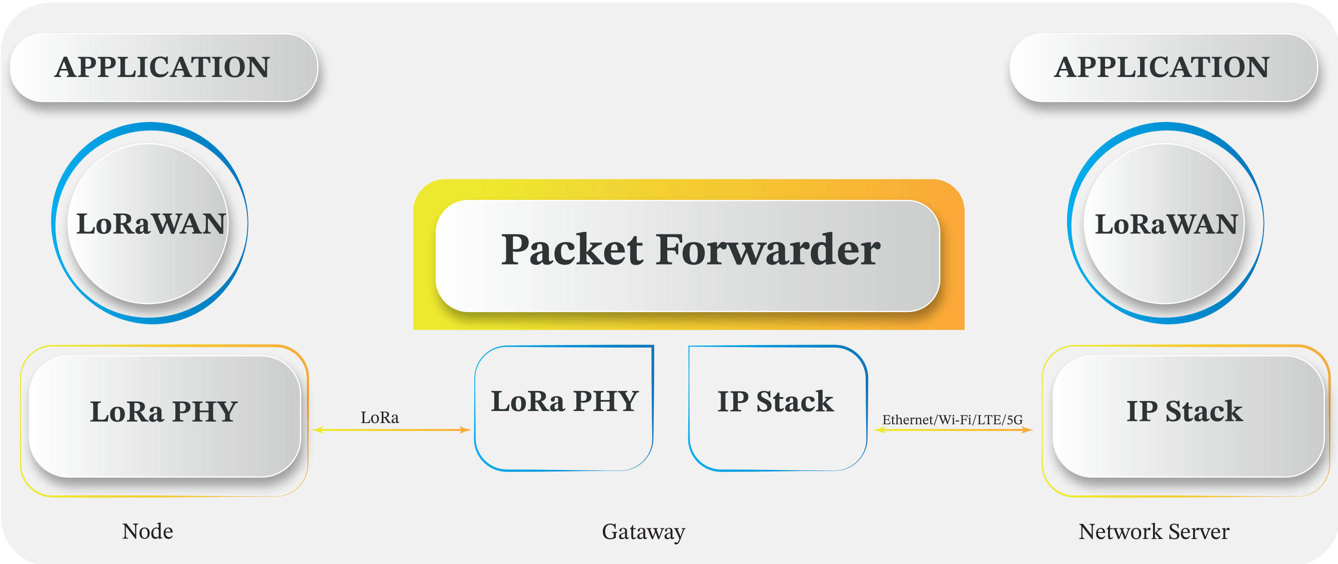

Figure 2: Architecture of LoRaWAN from the End Nodes to the Network Server

REGULATORY REQUIREMENTS FOR USE OF LORAWAN

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3.1 NETWORK COVERAGE

A LoRaWAN's network gateway can cover tens or hundreds of square kilometres, depending on the deployment. LoRaWAN's coverage is greater than any other standardised communication technologies such as Bluetooth, Zigbee, Wi-Fi or cellular. However, it still depends on obstructions (buildings, trees and hills), the environment (heavy rain) and technical factors (high-level radio interference, antenna type). The link budget is the primary factor in determining the range in a given environment for any communication – measured in decibels (dB).

3.2 LORAWAN FREQUENCIES

The LoRa Alliance defines regional frequency profiles to operate for different regulatory regimes worldwide. Table 1 lists the frequencies allowed to be used in some countries.

In Africa, very few countries have provided specifications of their frequency plans for LoRaWAN. At the moment, only countries in the Communications Regulators' Association of South Africa (CRASA)[1] under the CEPT Rec. 70-03 recommendation[2] have publicly made the adoption of EU863-870 and EU433 channel plans known. Given the ITU regional division, it should be noted that most African countries have adopted (most plan to adopt) the EU868 and EU433 plans. The LoRa Alliance has provided channel plan IDs for these channel plans as 1 and 4 respectively[3] . Both plans are considered as available for Short Range Devices (SRDs).

The Communications Authority of Kenya (CA) has also published the guidelines on the use of radio frequency (RF) spectrum by Short Range Devices (SRDs). CA defines SRDs as transmitters or receivers that are designed to operate over short-range, at low power levels and have the low capability of causing harmful interference to other radio communications services. The devices are

ITU Region	Country	Band/Channels	ITU Region
Region 1	United Kingdom	433.05-434.79 MHz 863-873 MHz	EU433 EU863-870
Region 2	United States	902-928 MHz	US902-928, AU815-928
Region 3	India	865-867	IN865-867

[1] https://www.thethingsnetwork.org/docs/lorawan/frequencies-by-country/
[2] https://docdb.cept.org/download/3700
[3] https://content.cdntwrk.com/files/aT0xNDc5NTI1JnY9MSZpc3N1ZU5hbWU9cnAwMDItMS0wLTQtcmVnaW9uYWwtcGFyYW1ldGVycyZjbWQ9ZCZzaWc9NzE5M2I2ZTJjOTNhYWJlNDgwOTg0MDZjMTc5NGNlNmM%253D

permitted to operate on a secondary basis on a non-interference and non-protected basis subject to national regulations and relevant technical standards. Internet of Things (IoT) devices fall in the category of telemetry SRDs.

SRDs are to be deployed in RF bands designated for Industrial, Scientific and Medical (ISM) applications as well as other RF bands not designated for ISM. The usability of the defined RF bands is based on ITU-R Radio Regulations and the European Telecommunications Standard Institute (ETSI) for devices.

While “LoRaWAN” is not exclusively mentioned in the guidelines, the 865-868 MHz band is made available for Tracking, Tracing and Data Acquisition under the requirement that the effective radiated power (ERP)[4] is 500mW. This means that the authorisation of LoRaWAN in Kenya is allowed as SRDs’ implementation in the EU868 standard with the 200 kHz channel spacing as provided by LoRa Alliance. Transmission is permitted within the frequency ranges: 865.6-865.8 MHz, 866.2-866.4 MHz, 866.8-867.0 MHz and 867.4-867.6 MHz. EU433 is not permitted at the moment for Kenya. However, based on the LoRa Alliance specifications, Channel-ID 0 is 863.1 MHz and Channel-ID 34 is 869.9. Therefore, in the implementations of LoRaWAN in Kenya, some of the transmissions can also take place in the 863 MHz.

3.3 TECHNICAL AND OPERATING CONDITIONS FOR LORAWAN

LoRa and LoRaWAN (classed as SRD devices) are expected to self-limit, adhere to the ≤ 10% duty cycle for network access points; ≤ 2.5% duty cycle otherwise and operate on a non-interference and non-protected basis and where necessary (scenarios of interference), will be reviewed by CA. They shall be used within premises or campuses and can be categorised as:

> *Networks where the service is provided to the public within a limited geographical location, such as in airports, train stations, bus stations, hotels, shopping centres, residential premises, libraries and parks.*

The antenna of the LoRaWAN devices is to be designed with the following considerations for the antenna types:

i. Integral (no external antenna socket).
ii. Dedicated (type-approved with the equipment).
iii. External (equipment type approved without antenna).

On interference mitigation, if any notification is provided by CA with regards to any identified interference by the LoRaWAN devices (even if the devices comply with the technical standards and equipment authorisation requirements), the devices are to cease transmissions until the interference is eliminated. In the context of our Imarika project, we should remain engaged with CA and be ready to take reasonable measures to ensure no interference is caused to other users within the band.

Other technical conditions are:

a. The frequencies, transmitting power and external high-gain antenna of the radio equipment must not be altered.
b. The radio apparatus must be operated within and must not exceed the technical parameters described in section 3.2.

[4] ERP s the total power radiated by an actual antenna relative to a half-wave dipole rather than a theoretical isotropic antenna.

BUSIA CASE IMPLEMENTATION AND GUIDELINES

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In the Busia use case, the implementation of LoRaWAN is interpreted to be adopted as the infrastructure that will support the deployment of 30 weather stations within the identified sites. While the physical site visits will provide clear description of the "real sites" where both the LoRaWAN gateways and the end devices are to be installed, this section provides guidance on the approach of deployment, cognizant of the CA's regulatory guidance (in section 3.2 and 3.3), the LoRaWAN Community's initiatives[5] of ensuring best performance of LoRaWAN networks in Kenya and Africa as well as the best practices to ensure that the setup of the infrastructure does not degrade the operation of other users in the 863-868 MHz band.

4.1 BUSIA SITES

As already identified, the subcounties within which the project is to be deployed are Butula and Nambale. These two subcounties occupy 247.1 sq. km. and 237.8 sq. km. respectively. This can be interpreted to mean that both subcounties have a radius of approximately 9km. From the submitted summary GIS report by iLabAfrica, the choice to have sensor points around an 8km zone is sensible. However, the installation of the network gateways should not only consider high-elevation areas as the potential installation sites but also evaluate the following:

1. *The identified sites for the installation of the devices. In principle, the dynamic of the design and the length of the antenna of the end-node with relation to Euclidean distance, will determine the reach of the data from the devices to the gateway. The length of the antenna is depended on the frequency of the radio transceiver end node (known as the quarter-wave whip antenna). Given that the EU868 MHz is the standard, the antenna should be calculated as:*

Length of the antenna =¼ (wave Velocity)/ (frequency))

In this case, it should be 8.63cm. The options of the antenna connections can be

i. Whip or wire antenna

ii. External antenna through a U.FL connector.

iii. External antenna through RP-SMA connector.

It should be noted that there have been scenarios of installing gateways on buildings with 6 dBi omnidirectional antennas at 20m Above Ground Level [AGL] and the reception was substantially great for a radius of 5km in urban areas)[6]. Rural areas such as Busia do not have a lot of building interference. Busia may be affected by vegetation (depending on the sites for the end nodes)[7] and weather changes. These two may hamper the signal propagation.

2. *The availability of both reliable power (grid or off-grid) and reliable backhaul.*

3. *Physical security of the gateway.*

Based on the strategic developments of LoRaWAN by the LoRaWAN Community, working in collaboration with CA and other research partners, the suggested locations of installing the infrastructure should be schools, universities or technical colleges. In both Butula and Nambale, the following institutions (with their coordinates) have been identified:[8]

[5] https://wirelessplanet.co.ke/lorawan-community

[6] https://www.researchgate.net/publication/355031523_Deployment_of_a_LoRaWAN_network_and_evaluation_of_tracking_devices_in_the_context_of_smart_cities

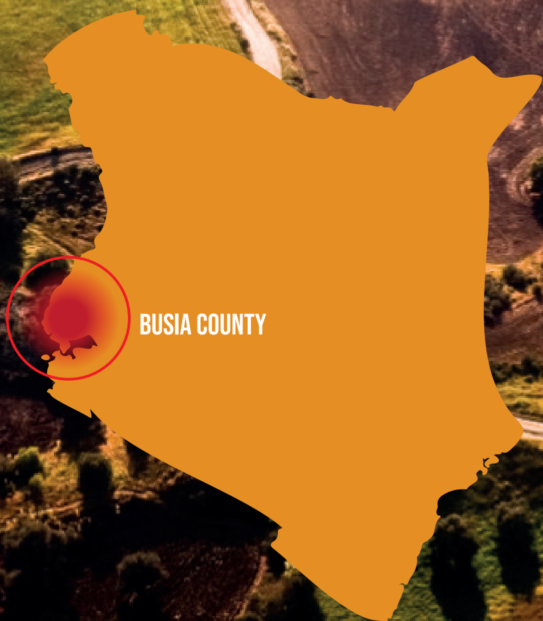
[7] Considering the installation of weather stations, this should be selected as open areas, hence allowing less vegetation as interference.

[8] The rationale of installing the network in the institutions is to guarantee physical security, have access to reliable power (if available) and backhaul (while Busia has connectivity challenges, schools may have a good cellular signal) as well enable development of ICT capacity for the institutions.

Figure 3 also shows the spread of these schools on the map of Busia County.

Subcounties	Site	Latitude	Longitude	Schools	Latitude	Longitude
Butula	Marachi Central	0.3498	34.2634	Bumutiru AC Primary School	0.4131	34.3057
				Kingandole Secondary School	0.3846	34.2979
				Bishop Nicholas Star Sikoma Mixed Secondary School	0.3623	34.2828
				Busiada Girls Secondar School	0.3144	34.2664
				Bukhalarire Secondarv School	0.3175	34.2842
	Elugulu	0.3626	34.3135	Esibembe Primary Schoo	0.4102	34.3113
				Sikura Primary School	0.3905	34.3198
				Bwaliro Primary School	0.3817	34 3274
				Madola Primary School	0.3405	34.3106
				Enakaywa Primary School	0.3404	34.3226
				The Oasis Academy	0.3429	34.3356
				Munga'mbwa Primary School	0.3265	34.3056
Nambale	Bukhayo East	0.4775	34.3579	Madende High School	0.4708	34.3252
				Mungatsi Technical Training Institute	0.4770	34.3265
				Sianda Primary School	0.4888	34.37251
				Buyofu Primary School	0.4970	34.37161
				St. Paul's Elwanikha Girls	0.4802	34.3616
				St. Anne's Green School Karungu Primary School	0.4752	34.3613
				St. Francis High School Sikinga	0.4756	34.3740
				St. Mary's Buyofu Secondary School	0.4992	34.3767
				Madibo Primary School	0.5310	34.3899
				Khulwanda Primary School	0.5184	34 3860
				Khayo Secondary School	0.5051	34.3910
				Mwenge Primary School	0.0540	34.6642
	Township	0.4611	34.1081	Bulanda Primary School	0.4502	34.1000
				St. Mathias Secondary School	0.4619	34.1038
				Busia Township Primary School	0.4717	34.1117
				Busia Township Secondary School	0.4717	34.1117
				St. Luke's Amoni Primary School	0.4661	34.1086
				St. Benadette Ojamii Primary School	0.4703	34.1201
				St. John Barrack Academy	0.4706	34.1180
				Ojamii Primary School	0.4655	34.1170

Figure 3: Identified schools to host the Gateways in Busia County



REGULATORY GUIDELINES & RECOMMENDATIONS

REGULATORY GUIDELINES & RECOMMENDATIONS

Based on the assessments of Busia sites, the following recommendations and regulatory guidelines should be considered prior to and during the deployment of the LoRaWAN network:

1. The choice of the sites where the weather stations (devices) are to be placed as well as the LoRaWAN gateways. Given Busia's rural location, coverage can go as long as 40km[9] without necessarily meaning raising the AGL height above 20m. To achieve better coverage at an AGL height of 20m, the implementation of the Gateway should use a 6-8 dBi antenna. The antenna of the weather stations (devices) should adhere to the mathematical requirement of 8.63cm.

2. Prior to installation of the LoRaWAN network, a pre-visit should be conducted to determine how many LoRaWAN gateways should be installed and in what sites (as recommended by the community, in this case should be which schools. However, in scenarios where it may not be possible to install within the identified institutions, alternative sites should be sought). This should be done, cognizant of power and backhaul requirements.

3. The antennas to be used on the gateways should be omnidirectional and preferably vertically polarised to not only deliver best performance of the signal but also enable better coverage.

4. Both devices and the gateways should be based on the EU863-870 channel plan which aligns to CA's guidelines for the SRDs. There have been scenarios of IoT devices in the 915 MHz deployed in Kenya. Such devices are not to be used in the Kenyan case as they pose interference to the incumbents in that band who are already licensed service providers.

5. The duty cycle requirements recommended by CA is sufficient as it allows 100 transmissions of 3.6 seconds within one hour. The device (weather station programmers) should develop the hardware software with this in mind.

6. With the challenges of cross-border interference that faces the Kenya-Uganda border, alternative sites for the Gateways should also be sought. There also exists a backhaul challenge on the Kenya-Uganda border. Hence, the LoRaWAN gateways should be positioned towards the centre of Busia County.

7. Given the requirement of the installation of the weather stations ('Siting')[10], the LoRaWAN gateways can be installed on top of buildings of the institutions in Busia County or at most 30m above ground level heights (if masts are to be used).

8. The team should also take note that at any point of identification of interference by CA, transmissions would have to be paused to eliminate the interference first.

[9] https://lora-alliance.org/lorawan-network-coverage/
[10] https://www.wunderground.com/pws/installation-guide