Title: Arid and Semi-Arid Lands Satellite (ASAL-SAT 1): Demonstration of a LoRa based ground sensor network for easing life in sub-Sahara Africa ASAL areas.

Primary Point of Contact (POC) & email: Kiruki Cosmas Raymond, cosmaskiruki@gmail.com
Co-authors: Rizal Suryana and Masaki Kataoka
Organization: Kyushu Institute of Technology

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Sustainable Development Goals addressed:

- Climate Action
- Life on Land
- Reduced Inequalities
- Good Health and well-being
- Sustainable cities and communities
- Industry, Innovation and Infrastructure

Need

Most of Sub-Sahara Africa is ASAL with pastoralism as the key economic activity. Environmental degradation and conflicts have contributed to poor quality of life in these areas. The ASAL-SAT 1 aims to demonstrate that these remote areas can have improved life if satellite services are designed to help solve their most pressing needs. There are no active satellite services dedicated to provision of these essential services to the herdsmen and pastoralists spread out across Sub Sahara Africa due to lack of a strong business proposition for mainstream satellites as well as lack of indigenous satellite/space expertise to implement such solutions.

Mission Objectives

1. Livestock and wildlife population mapping, enumeration and tracking.
2. Pasture and water identification and vegetation cover surveillance
3. Flash floods warning system

Concept of Operations

Store and forwarding, and remote sensing concepts form the backbone of ASAL-SAT 1. Kenya is chosen as demonstration site but the proposed technology can be applied across the Sahara. The ground segment will comprise of a cheap but advanced network of ground sensors based on LoRa (Long Range) technology for remote sensing and the ground station [1]. The space segment will include the store and forward functionality and the payloads for pasture identification and vegetation cover investigations.

Low Power Long Range (LoRa) modulation technique implemented across many RF chips offers low cost solutions to end users [2]. Such products are extremely admirable for offering solutions in the developing countries. Combining with a satellite service would make such solutions as the one being proposed here economically viable. Though this solution is not offered as a business model, its social impact is great and the governments of the involved countries can quite cheaply and effectively provide it as a service to its citizens to improve their lives and also to serve other national interests such as monitoring desertification, climate change and natural events such as the evolving Rift Valley split and flash floods.

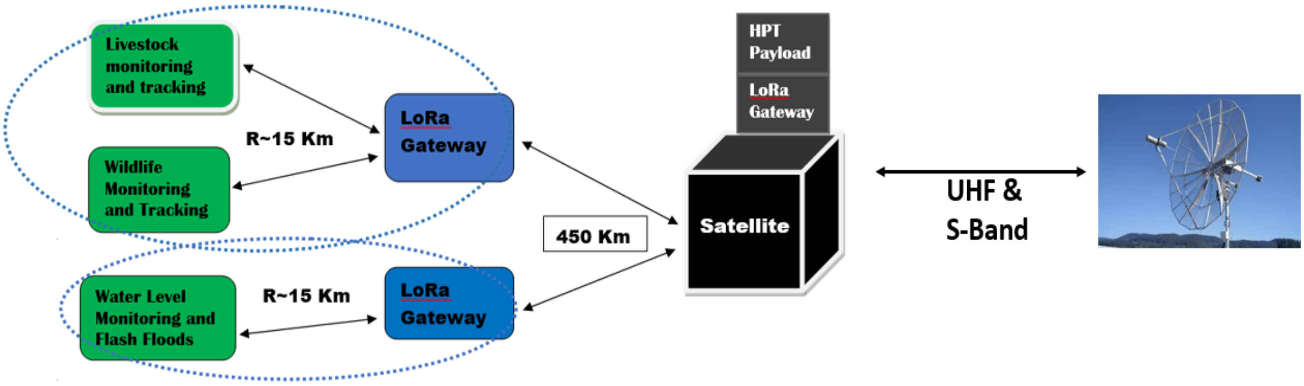


Figure 1: Overall System Configuration

1. Ground Segment: LoRa-Based Ground Sensor Network for Remote Areas

The biggest challenge that remote sensing always faced was lack of an energy/cost effective ground sensor network especially for remote areas that lack power and communication infrastructure. Collecting data from such areas and relaying it to central databases has always been a challenge. However, with a combination of LoRa devices and nano/micro satellites, this feat can be cost effectively achieved [3]. Use of Long Range (LoRa) Technology has the following admirable characteristics suitable for remote areas.

- Low-throughput communications with data rates ranging from 0.3kbps to 50 Kbps
- Operates on the 433-, 868- or 915-MHz ISM bands and Low power consumption
- Connects to sensors 15-30 miles away in rural areas

Since for the proposed ground sensor network, the data is quite small in the order of a few bytes per node, the LoRa is extremely suitable. Due to few obstacles in the vast savanna lands, the LoRa nodes can transmit over 15 kms. Thus the gateways can be spaced 30 kms apart such that each gateway covers a radius of 15 Kms. The gateways will augment the data collected from the different sensors within its 15 Kms radius and store this data till a satellite pass occurs. It will then transmit this data to the satellite.

a) Livestock and wildlife population mapping, enumeration and tracking

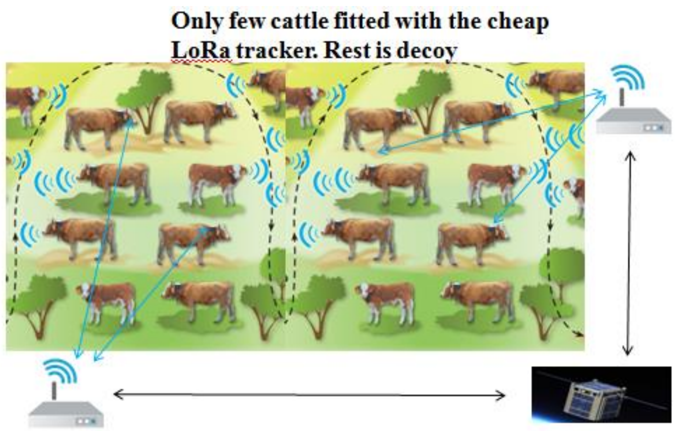


Figure 2: Livestock and Wildlife Monitoring

For cattle tracking, since the nomadic people have hundreds of livestock, only a few of the livestock need to have LoRa-tracking collars. Their movement will generally indicate the movement of the whole herd of cattle. This will be both beneficial to the local governments and the pastoralists. For the governments, they will have a rough estimate of the livestock keeping patterns and mapping of their population to help curb overgrazing that leads to desertification and communal conflicts as a result of sparse pasture. The pastoralists will benefit in keeping track of their livestock especially in the case of cattle rustling that is quite rampant across the Sahara among the cattle keeping communities. Consequently, with the knowledge that the livestock will be easily tracked, people will be discouraged from engaging in cattle rustling.

For wildlife tracking, there are numerous game reserves, national parks and ranches across the Sub-Saharan Africa. In Kenya there are dozens of such wildlife habitats. These areas are quite expansive and difficult to keep track of endangered species such as the elephants that are always a target of poachers. More so, it's important to monitor the movements of such wildlife to minimize human-wildlife conflicts which lead communities to become hostile to the efforts of wildlife preservation and promote vices such as poaching. The use of LoRa trackers will be appropriate as they are cheap, low power and the batteries will last for years before they need replacement.

The LoRa-enabled trackers will be randomly strapped on various parts of a given livestock. The rest of the herd will have similar but dummy straps that will make it hard for a potential rustler to pick out non-tracked animals.
End node will be a LoRa animal tracker – TM900-N1C1 [4]. This is a low-cost tracker that meets all the requirements for animal tracking in remote areas:

- Standby battery lifespan of more than 10 years
- Light weight and small in size- 3grams
- Transmission distances of over 10 Km
- Transmitting Power up to +20 dBm

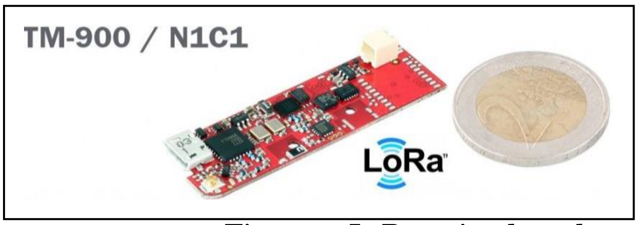


Figure 3: LoRa animal tracker

b) Flash floods/ Water Level monitoring and warning system

In the remote and pastoral areas, many of the rivers are seasonal. During the rainy season, the rivers suddenly get swollen and the residents downstream are always caught off-guard resulting in loss of lives and property. Incorporation of water level sensors and LoRa transceivers along such seasonal rivers can form a cheap yet expansive floods monitoring system. Water level sensors interfaced with LoRa transmitters (nodes) can be located at various points upstream of a major road/route or known hotspots. The LoRa nodes will then transmit to the LoRa gateway in their vicinity. The LoRa gateway will then transmit to the satellite.

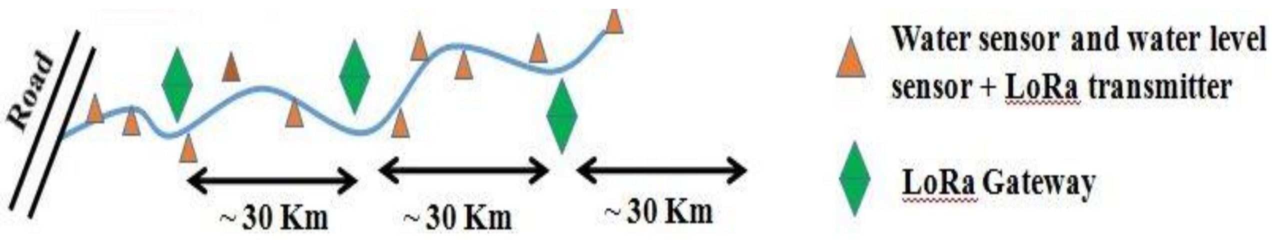


Figure 4: River and water level monitoring

A non-contact LoRa-enabled water level sensor from decentLab shown below is quite suitable.

- Resolution of 1-mm
- Maximum range of 10 meters (394 inches)
- Real-time automatic calibration (voltage, humidity, and ambient noise)
- 42kHz ultrasonic sensor measures distance to objects

Figure 5: LoRa based water level sensor

c) Pasture and water identification and vegetation cover surveillance

Majority of the pastoralists' communities across the Sub-Sahara, including in Kenya, are nomadic in nature. This means that they move from place to place in search of water and green pastures for their livestock. Such lifestyles would greatly benefit from a system that can help the nomads identify pastures and water points closest to their present locations. This can be achieved by use of a cheap yet high resolution imaging equipment. The High Precision Telescope (HPT) is a prime candidate for this mission. It will be presented in detail in the Space Segment.

Key Performance Parameters

i) Tracking updates at 30 minutes intervals

The livestock and wildlife tracking function should receive location updates at intervals of approximately 30 minutes. A minimum of 3 satellites placed on the equatorial plane 120° apart will achieve a revisit time of about 30 minutes.

ii) Ground resolution of 5 meters for pasture and water identification.

The nomadic lifestyle is informed by search of pasture and water. The ASAL-SAT should provide imagery capable of making this identification. The High Precision Telescope (HPT) will deliver this high resolution.

iii) Flash floods warning system updates of at least 15 minutes' intervals.

The minimum success level for flash floods data update is 15 minutes updates. For a near-real time update, 5 minutes will be an acceptable interval.

Space Segment Description

The ASAL-SAT 1 will contain two main payload subsystems: LoRa Gateways and a High Precision Telescope

a) **LoRa Gateways**

The novel part of the proposed solution is that the individual sensors on the ground don't need to establish a link with the satellites. Instead, the individual sensors (LoRa nodes) will transmit to the LoRa gateways in their vicinities. These gateways will augment data from different nodes and transmit to the satellite. Since LoRa is a modulation technique based on the Spread Spectrum, both the receiver and transmitter need to implement the same protocol. Hence on the satellite, a LoRa transceiver (which is another gateway) has to be implemented. This gateway will form a link with the various gateways on the ground during a satellite pass [5].

Figure 6: LoRa Gateway

- Gateways based on the SX1301 baseband concentrator
- More than 1 gateway can be deployed to serve several channel settings.
- Capable of simultaneous reception on several channels and implementing the LoRaWAN specification
- Sensitivity of up to -142 dBm

b) High Precision Telescope (HPT)

This imager has a ground resolution of about 3 meters. It has been successfully implemented in Philippines Diwata-1 and Japanese Rising-2 microsatellites. The Rising-2 microsatellite HPT has an observation area of about 3.2 km x 2.2 km. Its imaging system took high resolution images in 400 spectral bands with 5m GSD [6].

The other subsystems and components required for the space segment are summarized in the table below showing their power consumption and mass.

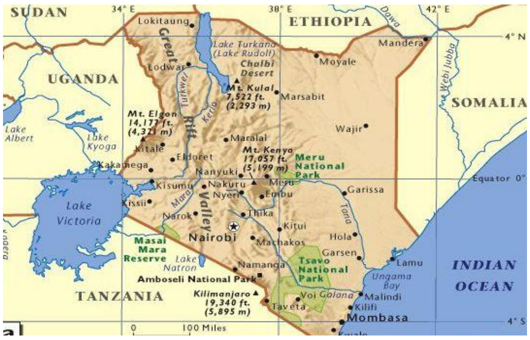
Table 1: Power Consumption and Mass of Satellite subsystems

No	Device	Mode	Power Consumption Idle (mW)	Power Consumption Peak (mW)	Mass (g)
1	LoRa Gateway + Controller	RX and TX	1500	3040	90
2	S-Band	TX only	0	9200	300
3	VHF (TT&C)	RX	200	200	85
		TX	700	1700	
4	HPT Imager		0	4000	3000
5	ADCS				
	Reaction Wheels	Idle	180	6000	760
	Sun Sensor		120	120	15
	GPS Receiver		120	120	47
6	OBC		400	2000	70
	EPS, Solar Panels and Batteries				2500
	Total		**3220**	**26380**	**6867**

Orbit/Constellation Description

The area of interest is the nomadic pastoralist in East Africa i.e. Kenya, Uganda, Tanzania. However, the test area will be Kenya. Nevertheless, this technology can be extended to cover all the other parts of Arica that practice nomadic pastoralism. Kenya lies within Longitude: 34° E and 42° E and Latitude: 4° N and 4° S

It's thus noted that the Equator neatly divides the country into two halves as shown in this image:



Northern and Southern part of Kenya extends a distance of:

Radius of Earth along Equatorial plane $\approx$ 6378 Km

$360° \approx 2\pi \, x \, 6378$ km

$1° \approx \frac{2\pi \, x \, 6378}{360} \approx 111.3 \, Km$

$4° \approx 111.3 \, x \, 4 \approx 445.3 \, Km$

Hence a satellite on the equatorial plane would adequately cover the whole of Kenya.

1) Minimum Elevation Angle

This is essential in the calculation of the Link Budget as it determines the surface coverage area that ensures a robust link with the satellite, whilst avoiding obstacles caused by natural barriers. Since the LoRa gateways will be operating on a very low power budget, the minimum elevation considered is very critical. A minimum elevation of 20° will be quite sufficient for optimal propagation losses.

2) Satellite Constellation

On the Equatorial plane, a satellite at an altitude of 400 km will make approximately 14 revolutions in a day. This means that a gateway will get a link to the satellite every 100 mins. The minimum success level for the cattle and wildlife tracking is location update every 30 minutes. **Three** satellites equally spaced 120° apart will achieve a revisit time of about 30 minutes. The minimum success level for flash floods is data update every 15 minutes. However, for a near-real time update, 5 minutes will be an acceptable interval. This requires an increase in the number of satellites for the needed revisit times.

Implementation Plan

This project proposal can be undertaken by the government through the Kenya Space Agency. For the larger sub-sahara project, the Regional Center for Mapping of Resources for Development (RCMRD) cab be a very critical partner of the project. This institution has membership of 20 African countries. Among its main roles include remote sensing, spatial data supply, surveying and mapping. The ground stations that can be used for the ASAL-SAT 1 include the Kenya Malindi Station (San Marco platform) and the University of Nairobi (Kenya).

Cost Center	**Cost (USD)**
20 Kg Satellite Build (10)	1,500,000
Satellite tests and transportation	1,000,000
Human Resource (Initial 3 years)	700,000
Launch (200 Kg class)	6,000,000
Total	**9,200,000**
Operational Costs Per Year (after launch)	**500,000**

References

List any technical references for your idea

[1] LoRa Alliance. White Paper: *A Technical Overview of Lora and Lorawan*; The LoRa Alliance: San Ramon, CA, USA, 2015

[2] Aloys Augustin, Jiazi Yi, Thomas Clausen: *A Study of LoRa: Long Range & Low Power Networks for the Internet of Things*: Sensors 2016

[3] SemTech Press Release: https://www.semtech.com/company/press/semtech -and-Lacuna -receiving-messages-from-space

[4] KCS TraceME TM-900/N1C1 GPS/RF- module datasheet

[5] LoRa Modules: http://www.rfwirelessiot.com/products/sx-1301-lora-module/

[6] R.K.D Aranas et.al :*Design of a free and open source data processing, archiving, and distribution subsystem for the ground receiving station of the philippine scientific earth observation micro-satellite* The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLI-B7, 2016 XXIII ISPRS Congress, 12–19 July 2016, Prague, Czech Republic