ns-3 simulation of Lion tracking for Gir forest with Machine Type Communication and LoRaWAN

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Abstract— Gir forest is well known for Asiatic lion all over the world. The lion landscape includes Gir national park and sanctuary which is spread over number of districts. Asiatic Lion is endangered species and Lion population estimate is an integral part of wildlife management. It is imperative to know the population estimation and population trend. Lion Tracking applications require low-rate, long-range wireless communication at a very low energy usage and cost. New technological advancement like Low Power Wide Area Networking technologies combine low data rate and robust modulation to achieve multi-km communication range. LoRaWAN is an appropriate technology for this use case since it handles the wide coverage area and the significant number of devices. The application based on technology provides real time tracking and also simultaneously population count. This paper describes the network topology and protocols and discusses ns-3 simulations results for Lion Tracking.

Keywords: LoRaWAN, Lion Tracking, Gir forest, ns-3 simulation, NAVIC, MTC

I. INTRODUCTION

The Gir forest is well known all over the world for the only wild gene pool and for the last home of the 'Asiatic lion (Panthera leo persica)'. The only surviving free-ranging population of the Asiatic lion exists in the Gir forest, Gujarat, India. The Nawab of Junagadh provided adequate protection to the animal and population of lion increased between the year 1904 to 1911. Gir was connected with the Girnar and Mitiyala hills by corridors of rough and semi-wooded and sparsely populated country as also with Barda and Alech hills and a wild wooded strip between Dhank and Chorwad along the sea coast. Figure 1 depicts map showing Gir National Park and Sanctuary [1].

Asiatic lion puts forth a conservation success story where the sub-species have recovered from the brink of extinction to disperse out of their last remain strong hold – the Gir forests. To understand the pulse of this population, a regular population estimation protocol is a must. Techniques used till date for estimation of lions includes: 1. Total count without correcting for detection bias. 2. Playback surveys 3. Faecal DNA sampling 4. Helicopter surveys 5. Mark recapture through individual lion identification.

Figure 1: Map showing Gir National Park and Sanctuary

With the advancement of scientific approach in the field of Nature Conservation and unification of Lion habitats under one State administration during the post Indian independence period, methods for estimation were improved and area coverage was defined and more reliable population estimations were made. After the formation of the Gujarat State, the Gujarat Forest Department has been estimating the Lion population five yearly. Lot of efforts and management energies goes in protecting the home of the Asiatic lions. In such circumstances it is imperative to know the population numbers and trends. It requires enormous efforts to count long ranging wild animals like lions by beat verification method and importantly, to count and observe every single animal. Figure 2: describes Regions of the Asiatic Lion Landscape [2].

Unlicensed Low Power Wide Area Networking, new proprietary radio technologies like SIGFOX and LoRa, have been developed and designed for machine-type communication applications addressing the ultra-low-power sensor segment, with very limited demands on throughput and reliable QoS. These technologies address limited power supply problem with a wireless connectivity between sensors. Ideally, a system where a sensor can run on a single AAA battery for years is preferred in such applications. Network operators are starting to deploy horizontal M2M solutions to cover a wide set of large scale verticals, using LoRaWAN technologies [3], [4]. The LoRaWAN technology with GPS based location tracking can be easily adapted for lion movement tracking and population counting in real time.

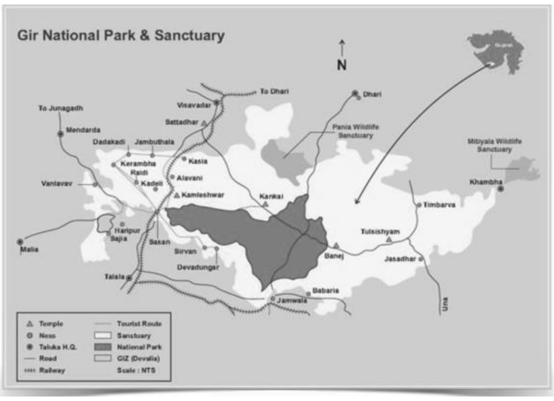

Figure 2: Regions of the Asiatic Lion Landscape
Source-14th Lion Population Estimation – 2015

II. OVERVIEW OF LORAWAN

LoRa is the physical layer and features low power operation (around 10 years of battery lifetime), low data rate (27 kbps) and long communication range (15 km in suburban areas). A single gateway can collect data from thousands of nodes deployed kilometers away. End-devices send data to gateways over a wireless communication in bi-directional mode, although uplink communication from end devices to the network server is strongly favoured. LoRaWAN defines three types of devices (A, B and C) with different capabilities [5]. Class A devices use pure ALOHA access for the uplink. After sending a frame, a Class A device listens for a response during two downlink receive windows. Downlink transmission is only allowed after a successful uplink transmission. Class A is the class of LoRaWAN devices with the lowest power consumption. Class B devices are designed for applications with additional downlink traffic needs. These devices are synchronized using periodic beacons sent by the gateway to allow the schedule of additional receive downlink traffic without prior successful uplink transmissions. Finally, Class C devices are always listening to the channel except when they are transmitting. The three classes can coexist in the same network and devices can switch from one class to another. Each frame is transmitted with a specific Spreading Factor (SF), defined as

$$SF = \log_2 (Rc / Rs),$$

Rs is the symbol rate,
Rc is the chip rate

Accordingly, there is a trade-off between SF and communication range. The higher the SF (i.e. the slower the transmission), the longer the communication range. The codes used in the different SFs are orthogonal. This means that multiple frames can be exchanged in the network at the same time, as long as each one is sent with one of the six different SFs (from SF=7 to SF=12). Depending on the SF in use, LoRaWAN data rate ranges from 0.3 kbps to 27 kbps.

The LoRa physical layer uses Chirp Spread Spectrum (CSS) modulation, a spread spectrum technique where the signal is modulated by chirp pulses (frequency varying sinusoidal pulses) hence improving resilience and robustness against interference, Doppler effect and multipath. Packets contain a 2 preamble (typically with 8 symbols), a header, the payload (with a maximum size between 51 Bytes and 222 Bytes) and a Cyclic Redundancy Check (CRC) field. Typical bandwidth (BW) values are 125, 250 and 500 kHz in the HF ISM 868 and 915 MHz band, while they are 7.8, 10.4, 15.6, 20.8, 31.2, 41.7 and 62.5 kHz in the LF 160 and 480 MHz bands. The raw data rate varies according to the SF and the bandwidth, and ranges between 22 bps (BW = 7.8 kHz and SF = 12) to 27 kbps (BW = 500 kHz and SF = 7) [6]. Frequency hopping 27 kbps (BW = 500 kHz and SF = 7) [7]. Frequency hopping is exploited at each transmission in order to mitigate external interference [8].

III. NETWORK TOPOLOGY AND PROTOCOL

The system consists of mainly five block: an end node-collar device, LoRa gateway, Wi-Fi links, VSAT network and application software running on server. The collar device sends the data over the air using the LoRa protocol and the nearest gateways receive the data. Then, the gateways forwarded the packets using Wi-Fi links to VSAT terminal which forward the packets to application software. The software displays the real time information about lions.

As per 14th Lion Population Estimation (2015) there are 523 lions in park. The network can easily track these many end devices without overload, in fact can support much higher capacity.

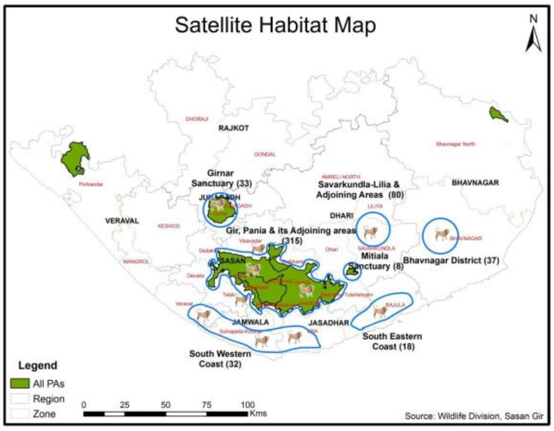

Figure 3: Satellite Map of Asiatic Lion Landscape
Source-14th Lion Population Estimation – 2015

Figure 4: LoRa Gateway location and coverage

The collar has solar cells with charging circuit, which will enable device life up to 10 years. Collar device is responsible for sending the data acquired from a GPS receiver over the air through a gateway to central location. The reporting period is kept as 4 hours but GPS location coordinates will be taken each hour and stored in device. Four GPS coordinates will be transmitted at one time each four hour. This will help save battery life at the same time coordinates of lion for each hour is available. Presently GPS is planned for location tracking but the collar device can be modified for hybrid location tracking i.e. GPS and NAVIC (NAVigation with Indian Constellation).

Alternatively, GPS free location tracking, only using LoRa devices, can be done which requires more number of Gateways for determining the position by trangularization. This approach increases device battery life beyond 10 years but is computational intensive and also provide approximate position of animal compared to GPS based coordination tracking [9].

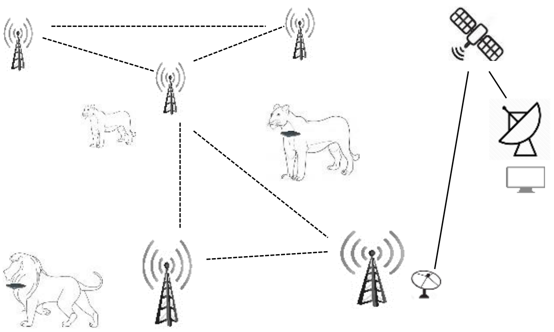

Figure 5 Network deployment

LoRo devices are connected to gateways in STAR topology. The main function of the gateways is to route the data received from collar device to the server. All the gateways are interconnected in MESH configuration. Figure 4 depicts LoRa gateway location and coverage. Entire Gir national park and sanctuary is divided in ten LoRa gateway zones which cover the area in overlapping fashion. The point to point Wi-Fi links with directional antenna are used for interconnecting gateways with LOS range up to 20 km. All the data of tracking is aggregated at one of the gateway and transferred to Gandhinagar (Gujarat capital) over VSAT link. Figure 5 depicts network deployment.

Redundant VSAT is also planned at geographical separate place with in sanctuary. The second VSAT is generally idle and becomes live if the primary VSAT of link fails for any reason.

The collar device has accelerometer, temperature sensor and RTC. RTC triggers on hourly basis LoRa device to get GPS coordinates and store them. Accelerometer detects the movement and if the movements are not detected then the location information is kept empty. This reduces the packet transmission overhead. The temperature of the lion is also sent along with coordination information so that health can be monitored and trigger is generated in case of unusual temperature variation. Four events taken hourly basis are combined in a packet which has four location coordinate and temperature information. The packet is transmitted at interval of four hours to LoRa gateway thus reducing transmission power consumption.

All the collar devices operate in class A operation, pure aloha for uplink. The collar devices periodically transit their location information. However, the class C in invoked in case the polling for entire lion population is to be done from application server. This provides real-time lion location and population count with health information.

IV. NS-3 SIMULATION AND RESULTS

The LoRa network for Lion tracking in ns-3 is simulated by defining communication/link parameters and determining packet reception probability for given coverage based on link parameters wilderness (rural) scenarios. End nodes are classified as LoRa class A network where transmissions are always initiated by the end devices. One of the parameters transmission periodicity from end node- collar device is kept as four hours which multiplexes four location and temperature readings taken on hourly basis.

The Gir forest area is divided in to ten zones each with 10 km radius. Taking upper bound of 1000 lions and simplifying with equal distribution across forest each zone is to have 100 lions. Each collar device transmits at regular interval of four hours meaning that there are six transmissions from each device, therefore 100 devices will have 600 transmissions each 24 hours. The traffic is very less even if all 1000 devices in single zones are considered there no chances of collision for 6000 data bursts for 24 hours. However, the transmission timing of each end device has to be carry chosen as to not to interfere or collide with other bursts transmission.

Entire network with no collisions the boundary conditions are coverage area of gateway and link parameters. The link measurement model, used to abstract the effects of propagation on signal strength as well as to average out small-scale fading and similar effects in rural-forest area. the link performance model, which determines the probability of correctly receiving a packet at reduced complexity, given the previously computed link strength, the amount of interferers and other system-level effects.

The power level that each gateway would receive from the end device is calculated. The gateway with the highest received power is assigned according to the gateway sensitivity: we assign the end device the lowest SF that would still be above the gateway sensitivity. Note that, due to the shadowing and the presence of tress, the closest gateway to a device may not always be the one that receives the highest power from that device.

The link measurement model aims at estimating the strength of the signal at the receiver side. Let us denote the transmitter and receiver antenna gain with Gtx and Grc, respectively, and the transmit power with Ptx. Then, the received power is expressed as

$$Prx = PtxGtxGrc\ L\ e\xi$$

where Gtx and Grc are transmitter and receiver antenna gain, Ptx is tramit power and L is the path loss and eξ is the lognormal shadowing component. The path loss L dB consists of propagation loss, and the forest/trees penetration loss,

$$LdB = LdB\ propagation + LdB\ forest$$

Assuming f = 868 MHz and height of LoRa gateway = 15 m,

$$LdB\ propagation = 120.5 + 37.6 \log10\ (R|km)$$

V. Conclusion

As a part of wildlife management the lion population survey is being carried out regularly at interval of few number of years. The method adopted is manual which requires enormous efforts to count long ranging wild animals like lion and there are chances of human errors. Low Power Wide Area Networking technologies combine robust modulation and low data rate to achieve large distance communication range. In this paper, implemented a system level simulator in ns–3 to simulate a whole LoRa network covering Gir park and sanctuary. The simulation results show that LoRa network can be deployed to have real time population tracking of lions.

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