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# Design Considerations and Data Communication Architecture for National Animal Identification and Traceability System in Nigeria

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# Design Considerations and Data Communication Architecture for National Animal Identification and Traceability System in Nigeria

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**Abstract:** Wireless communication systems and their supporting infrastructure continue to play a vital role in contemporary daily activities. Due to the unprecedented levels of interconnectivity achieved between wireless devices in recent times, new insights and paradigms for the robust deployment and better utilization of wireless communication systems are always of interest to many countries for socio-economic development. Present-day Nigeria is faced with the challenge of insurgencies whose financing has been linked to proceeds from livestock theft or rustling according to many scholarly works and news reports. To mitigate rustling and the sales of stolen livestock via identification and traceability from 'herds to markets to homes', the design considerations and data communication architecture for national animal identification and traceability system in Nigeria (NAITS) is proposed in this paper for safer and improved livestock farming and production. Particularly, technical insight into the co-use of radio frequency identification (RFID) and fifth-generation new radio (5G NR) technologies for the implementation of NAITS are highlighted and discussed in this paper for a prospective technological policy plan and development in Nigeria.

**Keywords:** 5G new radio, Cattle, Livestock, Nigeria, RFID, and Rustling.

## 1. Introduction

According to a recent report by the Food and Agriculture Organization (FAO) of the United Nations, Nigeria's national herd is estimated to comprise 18.4 million cattle, 43.4 million sheep, 76 million goats, and 180 million chickens [1]. With sustained good governance and a good economic scenario, Nigeria is projected to have a national herd compromising of 36.8 million cattle and 900 million chickens by 2050 in [1]. These statistics and other factors such as estimated Nigerian population growth and increases in milk and meat consumption show that Nigeria's livestock production is highly essential for the sustainability of both the Nigerian food system and the global food system [1], [2]. However, livestock production as a means of livelihood is faced with various challenges around the globe [3], [4], [5]. One of the primary challenges faced by livestock farmers in Nigeria is rustling [6]. Rustling is not peculiar; many developed and developing countries are wary of rustling [7], [8], [9].

Rustling is an old practice that is prevalent in livestock-rearing and nomadic communities [8], [10]. It is mainly characterized by stealing livestock from smallholdings or livestock farms and sometimes livestock markets [8], [10]. In present-day Nigeria, rustling has grown beyond mere pilferage of a few animals in nomadic communities for consumption as food by the rustlers to be a more sophisticated and organized crime [6], [11]. Today in northern Nigeria, from time to time, hundreds and thousands of livestock are stolen violently for economic gain leaving many livestock farmers either wounded or dead [6], [11]. Worse still, recent studies have attempted to establish links between the financial profits from weaponized rustling and the insurgencies in northern Nigeria [6], [11]. This situation calls for a rapid response and robust initiative from the Federal Government of Nigeria to efficiently manage livestock farming and sales in Nigeria.

Presently, the largest livestock market in Nigeria and possibly the largest in Africa, the 150 years old Maigatari market in Jigawa State, Nigeria, trades about 2.6 million dollars' worth of livestock every week at peak periods [12]. Most of the animals being sold or butchered in livestock markets and abattoirs across Nigeria (e.g., Wudil market in Kano State and its supply chains [13]) are usually unlabelled or unidentified. As a result, their sources and ownerships cannot be ascertained or verified. This gross lacuna allows animals obtained from weaponized banditry and rustling to be easily sold and slaughtered for cash without any consequence in Nigeria. Another challenge in identifying stolen livestock in Nigeria is that rustling often takes place with the connivance of security agents and outfits [6].

Even though the first author in our paper had co-proposed the implementation of national livestock identification and traceability system in Nigeria under the auspices of the RFID Research and Development Centre, Nigeria in 2017, and a stakeholder meeting and workshop on a National Animal Identification and Traceability System was held in 2018 to create awareness and to exchange views on the future design and organization of such a system in Nigeria [14], the system is still non-existent in Nigeria to the best of our knowledge (a summary of our findings is provided in Section 2). Hence, the design considerations and data communication architecture for the national animal identification and traceability system (NAITS) in Nigeria are being put forward in this paper.

To implement NAITS in Nigeria, some ideas can be borrowed from [15], [16], [17] and [18]. Particularly, countries like Botswana, Namibia, South Africa, Kenya, and Tanzania have either piloted or fully deployed a livestock identification and traceability system (LITS) [15], [19], [20], and [21]. Generally, LITS leverages on uniquely identifying livestock and collecting data bout livestock for tracking, monitoring, and health regulations. However, considering novel technological advancements which promote the ubiquity of wireless communications, the LITS available in many African countries and some developing countries still require state-of-the-art data communication architectures to enhance capacity and improve efficiency. For example, in [15], the LITS mainly included the range of data that identified the livestock and defined the points of commencement (e.g., cattle markets) and termination (e.g., abattoirs). To capture and store LITS data in [15], Open Data Kit (ODK) and an online database hosted on the International Livestock Research Institute (ILRI) server were employed, respectively. To ensure a low-cost and robust implementation, the hybridization of existing and relatively new wireless communication technologies is proposed for employment in the data communication architecture of NAITS. These technologies are radio frequency identification (RFID) and the fifth-generation new radio (5G NR).

RFID is an automatic identification (Auto-ID) technology and its first application dates to the second world war when it was employed in Identify Friend or Foe (IFF) systems [22]. A typical RFID system consists of a tag or transponder placed on an object (or animal in the case of NAITS) to be identified and a reader or an interrogator that queries the tag and retrieves the data stored on the tag [23]. In comparison to other similar Auto-ID technologies, RFID offers the added advantages of low cost, non-requirement for a line-of-sight, longer communicating ranges (particularly, for semi-passive and active RFID systems) [23]. More details on the operations of RFID systems can be found in [23].

5G NR on the other hand is a novel radio access technology (RAT) developed by the 3rd Generation Partnership Project (3GPP) for 5G mobile communication networks [24]. It is an integrated and highly capable air interface that supports enhanced mobile broadband, massive internet of things (IoT), mission-critical services, and so on [25]. In comparison to the previous generations of mobile communication networks and their RATs (which can also be deployed on 5G NR), 5G NR offers three times spectrum efficiency, 10 times decrease in end-to-end data latency, 10 times connection density, 10 times data throughput, 100 times traffic capacity and 100 times network efficiency [26], [27].

Particularly, 5G NR offers a maximum carrier bandwidth of up to 100 MHz and up to 400 MHz in the sub-6 GHz and millimeter wave (mmWave) spectra, respectively [26]. In terms of end-to-end communications, 5G NR provides ultra-reliable and low latency communications (URLLC) with 1 ms up to 10 ms end-to-end system delay and its ultrawideband network signal can reach up to 500 m without obstructions [27], [28]. Small cell technology can also be leveraged to deliver more signals which directly augment the speed and coverage of 5G NR [28]. In other words, future 5G-enabled areas can be expected to have several 5G NR small cells. More details on the capabilities and operations of 5G NR can be found in [24], [25], [26], and [27].

The remainder of this paper is organized as follows: a summary of our research findings on the state of rustling in Nigeria and the objectives of NAITS are presented in Section 2, the design considerations, and data communication architecture for NAITS are discussed in Section 3, Section 4 highlights the opportunities and challenges associated with the adoption and implementation of NAITS in Nigeria and the concluding remarks are given in section 5.

## 2. Objectives of NAITS

As briefly mentioned above, a summary of the recent research findings on the state of rustling in Nigeria based on available literature indicates the following [6], [11], [29]: (1) In present-day Nigeria, most of the livestock being sold at the livestock markets are usually direct proceeds of rustling perpetrated by bandits and insurgents. (2) Perpetrators of rustling in Nigeria are often militarized and can move herds (typically hundreds or thousands of livestock) freely for many days without being apprehended. (3) Rustling in Nigeria is an organized and pervasive activity that continues to pose serious threats to the economic and social well-being of many communities and livestock farmers. (4) Policing rustling in Nigeria is very challenging because perpetrators could be in collaboration with security agents and outfits. (5) Current preventive measures in Nigeria are yet to embrace a national animal identification and traceability system.

From the above research findings, it is obvious that a robust and non-biased approach is required to mitigate and/or eliminate rustling in Nigeria. As a wireless communication technology-based solution, the design considerations, and data communication architecture for NAITS are proposed in this paper for NAITS to meet the following primary objectives:

1. Identification (ID) of livestock in Nigeria through continuous digital census and data collection.
2. Livestock data accessibility to farmers, ranchers, sellers, buyers, relevant government ministries, departments, and agencies (MDAs), and local animal disease control officers in Nigeria.
3. Digital or electronic management system for the lifetime traceability of all livestock breeding, production, rearing, and marketing in Nigeria.

4. Integration of the digital management system with existing wireless communications (particularly, 5G NR), and information technology (IT) infrastructure in Nigeria.

To achieve the above objectives, the proposed NAITS will work as follows (see section 3 for more details):

**Step 1:** Purpose-built tags or transponders (they could also be collars) enabled for robust wireless communications holding unique data about each animal will be hygienically placed on the livestock to be tracked and monitored.

**Step 2:** Interrogators or readers capable of dedicated broadcast non-line-of-sight 5G mobile communications with the tags or transponders (they could also be collars) in Step 1 will be installed and placed at strategic locations and places (e.g., cattle farms, culling points, abattoirs, cattle markets, and so on) as fixed assets for continuous operations. They could also be handheld or placed on unmanned aerial vehicles or drones as mobile assets for co-operative periodic or routine operations alongside the fixed interrogators.

**Step 3:** The interrogators in Step 2 will query the tags (they could also be collars) in Step 1 whenever a feasible communication range is existent to retrieve data about the tagged livestock. The interrogators are Step 2 will also be capable of data and information interchange between themselves.

**Step 4:** The retrieved data in Step 3 are pushed as queries to a backhaul that accesses a national livestock database that holds more unique information about the livestock. The national livestock database will be regularly updated to ensure the unique information about livestock is not outdated or redundant.

**Step 5:** The unique information about the livestock in Step 4 is relayed back to the querying interrogators and it is used to ascertain the status quo of the livestock (e.g., stolen livestock, infected livestock, and so on).

## 3. Design Considerations and Data Architecture for NAITS

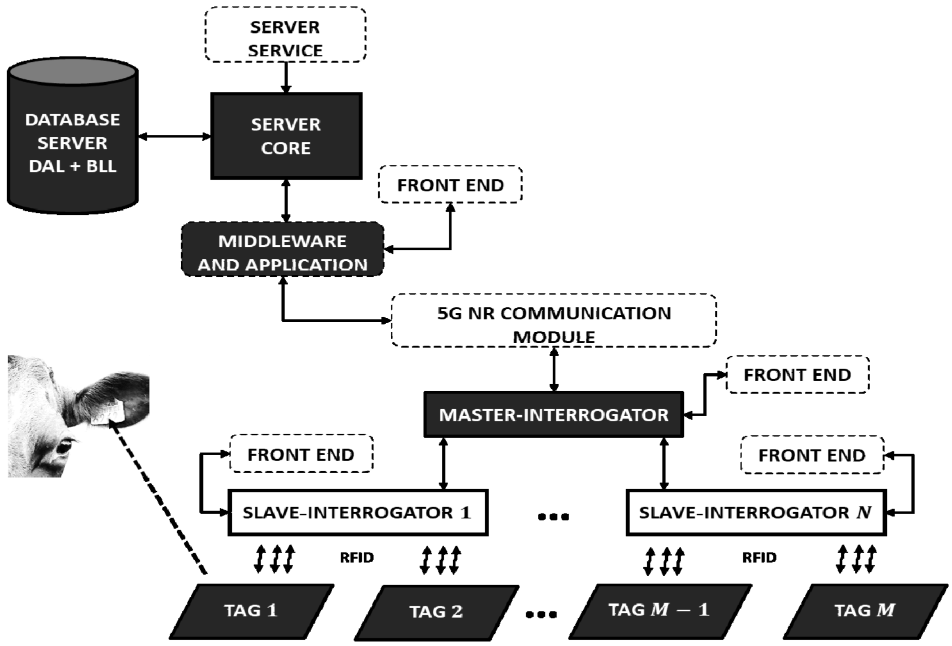


*Figure 1: Proposed RFID-5G master-slave architecture for NAITS.*

To implement NAITS, a master-slave data communication architecture that hybridizes RFID and 5G NR technologies, is proposed. The layout of the proposed RFID-5G master-slave architecture for NAITS is shown in Fig. 1, and it works using three principal data communication layers. The principal data communication layers are discussed as follows:

### *3.1 First principal data communication layer*

This is the first, and perhaps the most basic of the three principal data communication layers in the proposed data communication architecture for NAITS. In this layer, pre-configured RFID transponders are placed meticulously on every animal to be identified, monitored, and traced in Nigeria. As illustrated in Figure 1, the RFID transponders or tags can be placed on the ears of livestock and labelled uniquely (e.g., Tag 1, Tag 2, ⋯ , Tag M, where Tag M is the tag on the most recent animal added to the livestock database, according to Figure 1) by employing their generic inimitable electronic product code (EPC) or serial number or generating a new unique one. The tags to be used must be compliant with national laws (e.g., animal anti-cruelty, protection, and welfare laws in the Nigerian criminal code) and international standards (e.g., ISO 18000-6C, EPC Class 1 Gen 2, GS1, ISO-11784, and ISO-11785) for RFID use in animal tracking. The tags must also be capable of full-duplex (FDX) communications for their point-to-point connections to interrogators.

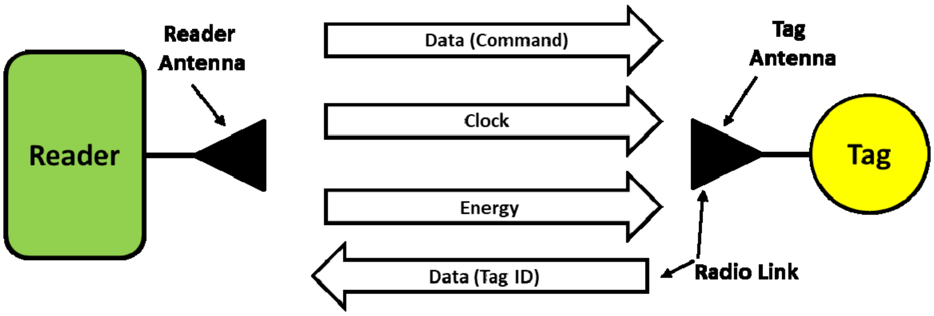


*Figure 2: A typical RFID system.*

Generally, RFID tags or transponders are designed to have integrated circuits (ICs) that are connected to an inductive antenna. The inductive antenna gets energized either by gathering emitted radio-frequency energy from interrogators in its vicinity through inductive coupling for passive RFID systems or via an onboard battery for semi-passive and active RFID systems [30]. It then induces the required current for powering up its onboard chip or IC and sends its ID to the interrogator via a radio link [30], as illustrated in Figure 2. The design specifications and functional requirements for the RFID tags or transponders can be according to the guidelines provided in [23], [30]. In comparison to other RFID tags available for animal tracking, passive, or semi-passive (i.e., battery-assisted) UHF tags are recommended for use in NAITS due to their moderate costs longer read ranges, ease-of-connectivity to interrogators, durability, low latency, and others [23], [30]. It is practically impossible to ascribe exact or specific costs to the components of proposed RFID systems. This is mainly due to the wide variety of RFID systems available in today's market and their varying costs. Typically, conventional waterproof livestock tags cost less than 3 to 15 dollars per tag, and active tags and/or collars with extended functions such as global positioning system (GPS) and wireless fidelity (WiFi) functions cost over 100 dollars per tag/collar [31], [32].

### *3.2 Second principal data communication layer*

In the second principal data communication layer, RFID tags or transponders from the first principal data communication layer are interrogated and/or read by any slave-interrogator in proximity or vicinity. For example, in Figure 1, Tag 1 and Tag 2 are interrogated and/or read by slave-interrogator 1. The slave-interrogator can be fixed (e.g., it can be placed at specific locations such as culling points, abattoir gates, livestock market stands or stalls, feedlots, and in grazing areas) or mobile (e.g., handheld interrogators and drone-mounted interrogators to be used by local animal inspection officers, and livestock farmers, and security officers). The primary function of the slave-interrogator in this layer is to obtain key unique information about livestock by querying the transponders placed on livestock.

The unique information obtained by the slave-interrogator from the RFID tag or transponder should include, primarily, the unique ID of the animal, and its geolocation. The unique ID and geolocation can then be looked up and cross-referenced in a central database (e.g., a national directory or database for all livestock in Nigeria) when the slave-interrogator sends a query to the master-interrogator to obtain more information about the animal (see Section 3.3). The slave-interrogator retrieves and reveals this information immediately to its operator as soon as the master-interrogator makes the information available. The slave-interrogators should offer efficient simultaneous FDX point-to-point communications with multiple transponders. They should also be capable of sending multiple queries to the master-interrogator, simultaneously. The design specifications and functional requirements for the slave-interrogator can be according to the guidelines provided in [23], [30].

### *3.3 Third principal data communication layer*

In the third and last principal data communication layer of the proposed master-slave architecture for NAITS, a master-interrogator that doubles as a hub and a controller within the data network is activated as soon as it receives queries from the slave-interrogators. As shown in Figure 1, the master-interrogator primarily features an application front end and a 5G NR communication module for robust data acquisition and transmission. The application front end and the communication module conjunctively provide a seamless gateway to a database server. On the database, the unique ID information embedded in received queries is looked up and cross-referenced with up-to-date additional details or information about tagged animals.

The database can be modelled and designed as a client-server database that employs both the data link layer (DLL) and the business logic layer (BLL) for querying and creating new information on the database [33], [34], as illustrated in Figure 1. The additional details available on the central database should include (but do not have to be limited to) the information provided in Table 1. Once the additional details (e.g., the information in Table 1) are retrieved by the master-interrogator, they are forwarded to the inquiring slave-interrogator for evaluation by its operators. As explained in Section 3.1, the exact costs for the components that make up an RFID system cannot be stated generically. Typical costs for interrogators can range from lower than or around 300 dollars to over 1,000 dollars per interrogator depending on the embedded functions, communication protocols, and configuration [31], [32]. The design specifications and functional requirements for the master-interrogator can be according to the guidelines provided in [23], [30].

*Table 1: Livestock identification and information for proposed NAITS.*

| Item | Description |
|---|---|
| 1 | Tag number |
| 2 | Date of birth |
| 3 | Sex |
| 4 | Breed |
| 5 | Identity of the genetic parent |
| 6 | Date and details of movement |
| 7 | Name of farmer or owner |
| 8 | Name of farm or holding |
| 9 | National livestock passport number |
| 10 | Health and vaccine information |
| 11 | Emergency Contact |

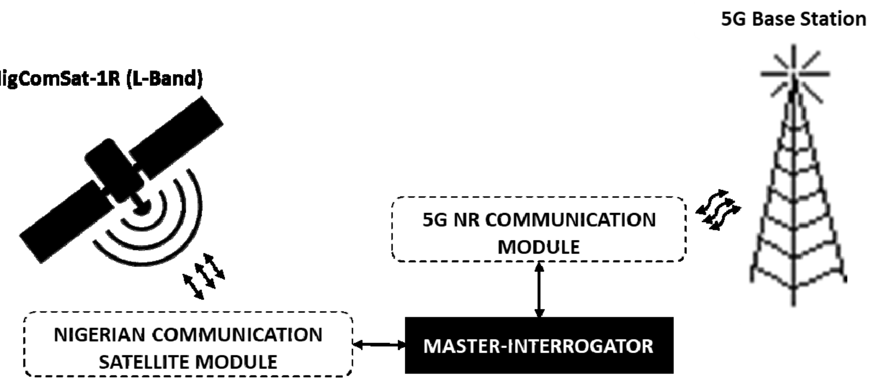


*Figure 3: Enhanced master interrogator for the proposed NAITS.*

### *3.4 Other Design Considerations*

In the third principal data communication layer of the proposed data communication architecture for NAITS, the 5G NR communication module, on-board the master-interrogator, ensures data bandwidth, data throughput, and data latency are highly efficient for effective and robust wireless communications. Note that the application front ends of the master-interrogator and slave-interrogator allow for the configuration, reconfiguration, and automation of their operations without or with minimal human intervention. As shown in Figure 3, the data communication architecture can also be made more robust by enabling it for dedicated satellite communications (e.g., via the NigComSat-1R using an L-Band transceiver [35]).

In grazing areas or nomadic routes where terrestrial communication networks are either unavailable or not fully operational, the inherent capacity of satellites for broad area coverage may be harnessed through the use of remote sensing data and geographic information system (GIS) images about livestock movement and presence. Such data can be collected using dedicated low earth orbit (LEO) satellite communication systems [36]. Despite the promise of robustness and ubiquity, satellite communication systems require huge capital investment in terms of satellite ownership and others. For instance, the cost of building, launching, and operating a traditional satellite (communication and observational) over its lifetime may be well over 300 million dollars [37]. Recent capacity pricing trends for leasing high-throughput satellite (HTS) and fixed-satellite service (FSS) satellites also show costs ranging from 800 dollars per MHz for some applications to around 8,000 dollars per MHz for data-intensive applications [38], [39]. Hence, this approach is only recommended if the return on investment is estimated to be sufficient to accommodate any huge initial investment. The communications between the slave-interrogator and master-interrogator can also be 5G NR-enabled provided it is also cost-effective.

Considering the network topology of the proposed data communication architecture for NAITS (see Figure 1), it is strongly recommended to have a redundant master-interrogator within the data communication architecture to avoid downtimes in case the master-interrogator (i.e., the hub and controller of the network) fails.

## 4. Opportunities and Challenges

Apart from the vivid mitigation of rustling and curbing the sales of stolen livestock in Nigeria, NAITS will offer the Nigerian government a robust digital platform for the monitoring and evaluation of livestock farming and production in Nigeria. As result, the livestock markets in Nigeria (which are currently limited to Nigeria and her neighbouring countries) will ultimately become opened for global or intercontinental trade. This is because NAITS captures the health and vaccination information of the livestock which is a prerequisite for the global trading of meat and milk. NAITS will also allow for better control and management of influenza or flu and other diseases common to livestock. For example, even though trypanosomiasis (sleeping sickness) is no longer a prevalent public health problem in Nigeria, most of the livestock in Nigeria are still at the risk of sleeping sickness, which leads to their morbidity, loss of weight, and likely mortality [39]. Reduced livestock production because of diseases such as sleeping sickness directly leads to decreased availability of milk and meat protein which may hinder socio-economic development. NAITS will help in the quick identification and isolation of affected livestock via the health and vaccine information

Despite the excellent opportunities which NAITS will avail Nigeria, there are economic, political, and social factors in present-day Nigeria that may either delay or completely hinder its full adoption and implementation. Some of these challenges include (but are not limited to): (1) The cultural philia nomadic farmers in Nigeria have for their livestock may hinder them from tagging and identifying their livestock. (2) The necessary traditional laws, legislative acts, and government policies required to support the identification and traceability of livestock production and management in Nigeria are still not consolidated as at the time of this research endeavour. (3) The technological infrastructure in Nigeria is yet to be on par with what is obtainable in other countries where similar systems to NAITS have been deployed and are currently in effect. For example, the database centre for NAITS may experience a reduction of services or rapid shutdown or even a complete system blackout during unexpected power fades or power failures which are common in Nigeria due to poor power infrastructure.

## 5. Conclusions

In this paper, the design considerations and data communication architecture for the national animal identification and traceability system (NAITS) in Nigeria are proposed. The adoption and implementation of NAITS by the Nigerian government through its Federal Ministry of Agriculture and Rural Development will offer an excellent way to address the prevalence of weaponized rustling which now arguably funds insurgencies in Nigeria. The hybridization of a popular automatic identification technology (i.e., RFID) and a relatively new wireless communication technology (i.e., 5G NR) is typified in the proposed data communication architecture for NAITS. At this stage, the scope of work in this study has not considered the practical implications of implementing a proof of concept for the proposed NAITS. In the future, a pilot study will be planned and conducted to have a proof of concept or prototype implementation of the proposed NAITS on a small scale through the support of the Nigerian government and international development partners.

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