IoT in the Agribusiness, a Power Consumption View

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***Abstract*—In this work, an experimental energy consumption comparison for (primary)battery powered devices for the agribusiness industry is presented. Recent industrial developments will be presented from inside: a Remote Telemetry Unit (RTU) using 3G/GPRS to monitor temperature and humidity in agriculture later adapted to process acoustic signals for illegal logging detection, and a micro-power LoRa based oestrus detection platform for dairy farms. A complete set of the measurements is presented, of the energy necessary for data packet transmission, which makes possible to draw valuable conclusions for the development of IoT devices for the agribusiness.**

***Keywords*—IoT, agribusiness, low-power, remote sensing, sensor network.**

I. Introduction

Internet of Things (IoT) protocols and hardware embodiments, are rapidly changing production systems within the agribusiness from cattle, pigs, poultry industries, to intensive agriculture, timber industry or fish farms and fisheries; but agribusiness is an enormous market that yet lacks massive technology adoption. For the agribusiness, power consumption and cost constrain impose a different approach for data communication in comparison to smart cities (i.e. urban transportation, or white goods). It is possible to group agribusiness applications in two categories, single nodes connected to the Internet or a VPN (like illegal logging detection nodes in Fig.1(top)), and sensor networks (like tracking individual cattle animals in Fig.1(bottom)). In the former a single or a few nodes send data/alerts to the farmer/ranger server, and in this case has no practical sense to deploy a private wireless LAN in the farm thus existing services normally provided by mobile operators are utilized (GPRS or 3G because LTE has yet less coverage in the rural area[1]). Third party networks in the ISM band (like LoRa, RPM, Sigfox, etc.) can be also employed but also have still little coverage in the rural area. For applications like cattle tracking in Fig.1 with tens to thousands of nodes, cost constrains make not possible to use individual GPRS/3G/LTE modems each node thus a farm-area network (FAN) is normally deployed, with a star topology to avoid the extra power consumption of mesh networks. IoT in the agribusiness has the following characteristics:

- Deals with commodities thus IoT nodes must be low cost.
- There is no access to an external power supply, rechargeable batteries are not rugged/reliable enough, and are expensive, thus primary batteries are preferred.
- The user has no easy access to the node once installed thus shall operate few years without maintenance.
- The amount of data to transmit is low.

So, power consumption seems to be the most critical aspect to develop IoT in agribusiness production sites, and from this perspective which technology a designer should select from the existing and future ones to connect IoT nodes to a host server In this work a complete set of measurements of the energy necessary for data packet transmission is presented, using the developed examples in the abstract:

- Battery powered RTU: a 3G/GPRS connected acoustic signal processor for illegal logging detection [2].
- Cattle oestrus detection: a micro-power LoRa based platform for dairy farms, using an accelerometer for heat detection [3,4].

Based on these measurements it was possible to compare 3G against GPRS for present developments, and to estimate what is possible to expect from low data-rate IoT specific technologies like LoRa, or others to be deployed in the near future like narrow-bad LTE [5][6]. We are in a hinge moment where some technologies will be adopted, thus at the end we venture to make some predictions about the future of IoT in farms and other rural production units, including trends like IoT-based geo-localization, virtual fences, etc.

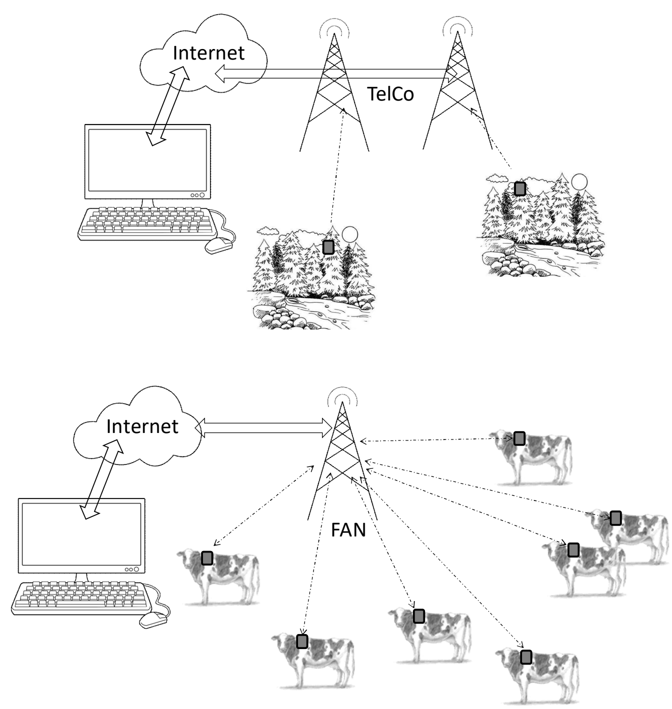

Fig. 1: Top: a scheme of the acoustic illegal logging detection RTUs network connection. A few RTUs are placed in timber forests, to listen for a few years with a single primary battery for chainsaws and other logging equipment. Each RTU is connected to the cloud through existing 2G/3G networks. Bottom: A scheme of cattle tracking example, like in the oestrus detection system. Hundreds IoT nodes are connected to a single gateway in a star topology, constituting a "Farm Area Network" (FAN). Node-to-gateway distance can be up to a few kms.

II. A 3yrs Battery Powered RTU for Illegal Logging Detection, GPRS-3G Comparison

The proposed RTU was first aimed at temperature/humidity monitoring in farms and was later adapted for illegal logging detection using a microphone and custom DSP. The RTU sends alarms and daily data to a host server through the GPRS or 3G telephone company (TelCo) carrier network using a low-cost modem and is powered for 3 years from a single 2200mAh Lithium-Thionyl primary battery (LiThi, having good energy density and low series impedance). In Fig. 2 the system's block diagram is shown, implemented for minimum power consumption. It includes a micropower analog MEMs microphone (ICS-40310) and since its output is relatively low a 50dB gain 40dB/dec bandpass-amplifier is also included. The amplifier is a 2nd order Butterworth filter in the band from 20Hz to 300Hz (adequate for logging equipment detection) using two micropower LMP2231 Opamps. The CPU is an FRAM-MSP430 with 64kByte memory, FRAM consumes minimum power but also resulted very helpful to implement the data logs. Two different prototypes were developed: one using a SIM900 GPRS modem the other using a SIM5360 3G one (same manufacturer), to empirically investigate the most power efficient technology. According to the datasheets, modems can consume high current peaks, thus a 10.000µF electrolytic tank capacitor was placed in parallel to the battery. A DC/DC converter powers the microcontroller and analog circuits while the modem is directly connected to the battery. The CPU is normally in 'sleep' mode consuming almost no power and wakes up regularly to process a buffer of DMA-acquired ADC samples and perform other tasks if necessary. The RTU sends an alarm upon detection of a chainsaw-like ambient sound to inform a possible illegal logging event. At the present a simple acoustic power detection algorithm is being employed in the CPU (FIR filter + 15 minutes power average in a sliding window + threshold detection), but the RTU is generating also an ambient noise and acoustic events data base, to help in the set-up of more intelligent algorithms. Thus, certain acoustic time series and statistical data are transmitted each day to the host computer. The focus of this work is to measure the RTU power consumption, the experimental setup is shown in Fig. 3, the measurement resistor is changed depending on the range of the current consumption (CPU sleep, modem TX/RX, etc.) from a few hundred Ω to a 60mΩ calibrated copper wire. Several power measurements were obtained to compare 3G against GPRS while varying the signal strength, packet length, network operators, etc. to determine the best data communication strategy. In Fig. 4 a typical power consumption profile is shown, in this case for modem power-up and TelCo network registration. The total energy consumption for the process is integrated:

$$E = \int_{\Delta t}(V_{CC}\cdot I_{CC}(t))\cdot dt \qquad (1)$$

Once the modem is registered it is ready for data packet send through a http POST. Several measurement series were performed for average and low (below -95 dBm) signal, for two different network operators, several packet lengths, for network registration, etc. All the measurements in this work correspond to the average of tens to a few hundred measurements. In Table I, energy consumption in several cases is shown. Note the GPRS prototype consumes less energy than the 3G one. Measurement results allow to set the communication strategy (the way the modem will be operated to minimize power consumption). One option is whether to turn the modem off while waiting for the next data packet,

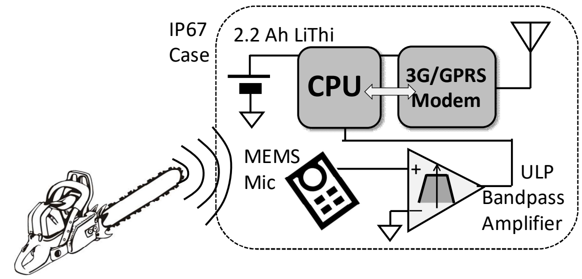

Fig. 2: The fabricated acoustic RTU block diagram including CPU, MEMs mic, analog amplifier/filter, and modem.

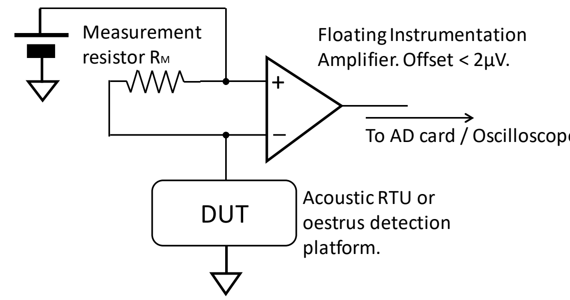

Fig. 3: Experimental current consumption measurement setup.

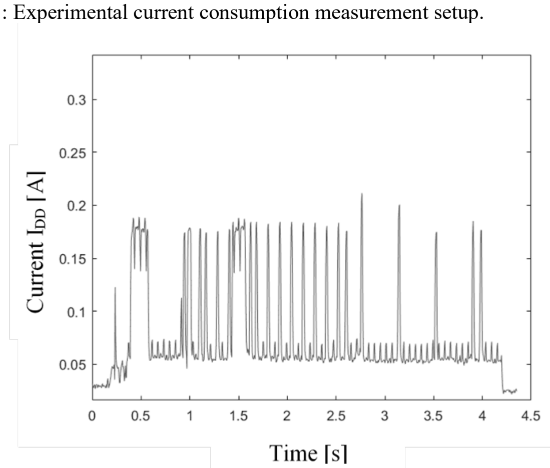

Fig. 4: Sample GPRS modem turn on measured current consumption $I_{DD}(t)$. The total energy in Joules is integrated using (1).

Table I. Measured energy in Joules, for different RTU operations using GPRS or 3G modem.

	Energy consumption [J]			
Network registration + 2k data transmitted + server Ack				
	GPRS		3G	
Average signal strength	10.2		27.8	
Low signal strength	25.9		31.4	
Data packet send and wait for server reply (GPRS)				
Payload [Bytes]	2k	4k	8k	16k
Carrier A – Average signal	18.3	19.3	25.2	34.8
Carrier A – Low signal	18.6	19.6	25.5	35.0
Carrier B – Average signal	26.4	27.3	33.2	42.8
Carrier B – Low signal	13.4	14.3	20.2	29.8

or to keep it on and registered to the network all the time. The key aspect here is the power consumption in the modem´s idle state because even without doing nothing it must send regular messages (approx. each 15 mins) to the base station to keep registered. Several one-hour records of energy consumption were measured in the idle state, arriving to an average of 18.4mJ per second that at a first sight is unacceptable for a battery powered RTU. Since the RTU is expected to communicate in the range of only once a day, it will register the modem in the network prior to each time is necessary to send data to the server, it is still necessary to set the optimum data payload. Agribusiness IoT nodes generally collect little amounts of data from sensors to send to a server, relevant data will be stored and only transmitted once a day (or an alarm), if possible, in a single data packet. Measured per-packet energy consumption is shown in Table I and Fig. 5. Note only for packets larger than 2-4kbytes the energy consumption per-packet is almost proportional to the packet size, tends to a 1.3mJ per byte value. An optimal packet size of 4 Kbytes is selected because sending less information results in almost the same energy consumption. This "fixed price" for the data packet energy is associated to a large amount of signalization messages between the modem and de TelCo. Finally, also the time it takes (once the modem is registered) a packet to be transmitted until the server's reply is received back, was measured. The average results span from 7s for GPRS up to 12s using 3G (low signal strength).

III. A 5μA LoRa Platform for Cattle Oestrus Detection

Cattle heat (oestrus) detection has become an important problem to solve at dairy farms. Tracking the animal's physical activity is known to be an effective way to check heat [3,4]. In this section, state-of-the-art technologies (like micropower accelerometer, FRAM-CPU, LoRa transceiver) are combined in a micropower long range wireless platform in the star topology of Fig. 1, for activity data collection and oestrus detection. The device reached an average consumption of 5 uA while collecting data and transmitting each 15mins with > 10 km communication distance. In Fig. 6 the system's block diagram is shown, implemented for micro power consumption, and having several points in common with the RTU of the previous section. The system includes a micropower accelerometer (ADXL362) with SPI digital output, consuming less than 2 μA at a 100 Hz output data rate (is capable to buffer

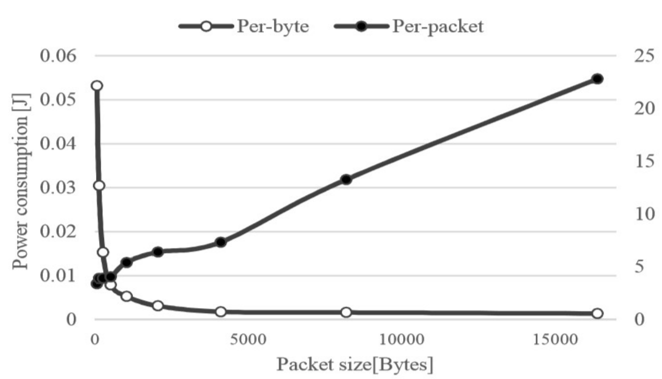

Fig. 5: Measured energy consumption per-packet and per-byte depending on the packet size for the RTU with GPRS network. Note the optimum @2k-4kByte payload.

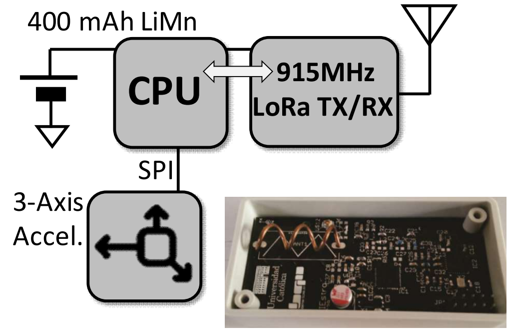

Fig. 6: The fabricated oestrus detection platform block diagram and photo.

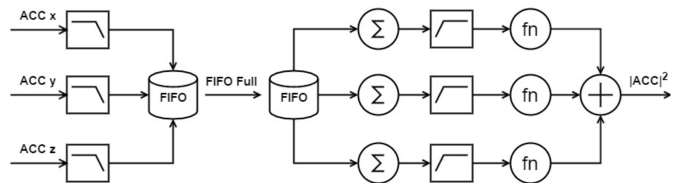

Fig. 7. Data acquisition and processing block diagram.

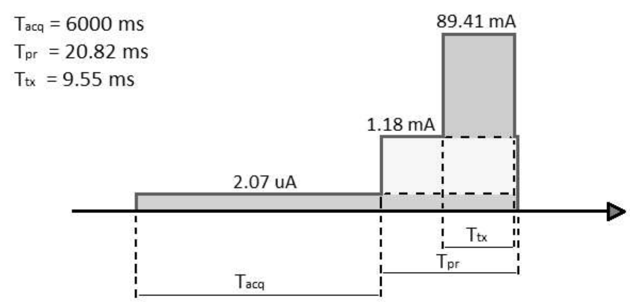

Fig. 8. Measured supply current I_{DD} and time for a acquire(sleep), data processing, and LoRa TX cycle.

a few 3-axis acceleration samples) and 270 nA when in motion triggered wake-up mode. The CPU is the same as before, and a custom LoRa transceiver based in a SX1276 IC was developed. Bandwidth options range from 7.8 kHz to 500 kHz with spreading factors ranging from 6 to 12 and covering all available frequency bands [7]. While there is still a discussion about the performance of LoRa in the presence of interference in cities, it seems a very good solution in the case of farms with a less polluted RF spectrum; thousand nodes (cattle heads) can be tracked in several kms around. The system is intended to be used on collar for cows in an aggressive environment, with a battery duration of a few months to ideally several years. The major limitation is not power consumption but current peaks only present during transmission estimated to be about 125mA for a few ms. A 3V, 400mAh primary Polymer Lithium Manganese Dioxide battery with enough maximum pulse current rating was chosen (up to 150mA for 15s). The battery size is 30×39×2.3mm. Wireless communication is necessary since there is a narrow time window for the heat detection, and is necessary to procure a cheap, low-power but long-range solution, to cover cattle raised in the open, in relatively large farms. LoRa technology was selected, and a LoRa gateway can easily implement the FAN of Fig.1. In this work first a class A node type was utilized (point-to-point) for minimum power consumption estimation, and later LoRa-WAN protocol measurements / estimations were performed without a remarkable difference. Each cow has a collar or eartag, which includes the system in Fig.6. For the firmware, a round-robing with interrupts architecture was selected, most of the time, the MCU and LoRa transceiver are in sleep mode, while the accelerometer gets information and stores it in its FIFO (up to 6secs - 150 samples) buffer. Periodically the MCU wakes up and process the data. Each 15mins to an hour, data is processed and transmitted via LoRa wireless protocol. The node sends an alarm upon detection of possible oestrus or statistical info at regular time periods of 15 mins. At the present a simple kinetic detection algorithm is being employed in the CPU (numeric bandpass filter + power average in a sliding window + threshold detection) as depicted in Fig. 7 but like in the case of the RTU some operations are also performed, to help in the set-up of more intelligent algorithms. Power consumption measurements were obtained using the experimental setup of Fig. 3, the measurement resistor is changed depending on the range of the current consumption (CPU sleep, CPU data processing, LoRa TX/RX, etc.). In Fig.8, a measured typical current consumption profile is presented; measured system "sleep" current was only I_{DD} = 2.1 µA, measured CPU data processing current was I_{DD} = 1.18 mA (during 11.3ms each 6s), and transmitting current was I_{DD} = 89.4mA (during 9.6ms each 6s for a small 8bytes data payload per packet). The system worked as expected, data was acquired and transmitted above 10kms to the Server, reaching very good power consumption reaching an almost 3-year estimated battery life while transmitting each 15 minutes. In Fig. 9 estimated battery life is shown depending on TX rate and battery capacity. It should be pointed that LoRa effective power consumption depend on several configurable parameters like bandwidth, spread factor, frequency, preamble, coding, etc.. Fig. 8, Fig. 9, correspond to a typical configuration that was able to comfortable cover 10kms distance with minimum errors in the wireless link. Finally, note the 1-2 orders of magnitude difference in power consumption in comparison to de modem-based RTUs of the previous section.

IV. Conclusions

In this work, an empirical study of power consumption on developed industrial devices for the agribusiness is conducted, comparing GPRS, 3G, and LoRa (the latter an example of several emerging specific IoT protocols/hw embodiments). As a conclusion old GPRS is preferred to 3G while waiting for modern IoT networks being deployed by TelCos. When comparing GPRS/3G to LoRa, the latter consumes 1-2 orders of magnitude less power for a normalized data packet. But a great advantage of LoRa is that the optimum packet size is a few bytes, well below the 2kBytes to 4kBytes of GPRS-3G. The great advance with LoRa and probably other IoT-native technologies, is the great reduction of signalization messages consuming a lot of power, that pushes the minimum energy for a data packet sent in GPRS/3G to a few Joules.

Specific IoT devices (like LoRa) consume more than an order less power but require a specific network and are no yet as cheap as necessary for the agribusiness. Thus, it will still be a couple of years to have a clear picture of the dominant technologies. For the agribusiness application the key aspects are power consumption and cost, but some related features especially IoT-based geo-localization [8] that is being developed (avoiding power-hungry GPS electronics) can definitely tip the balance for one or another technology.

Acknowledgment

Part of this work has been supported by ANII postgraduate grant program.

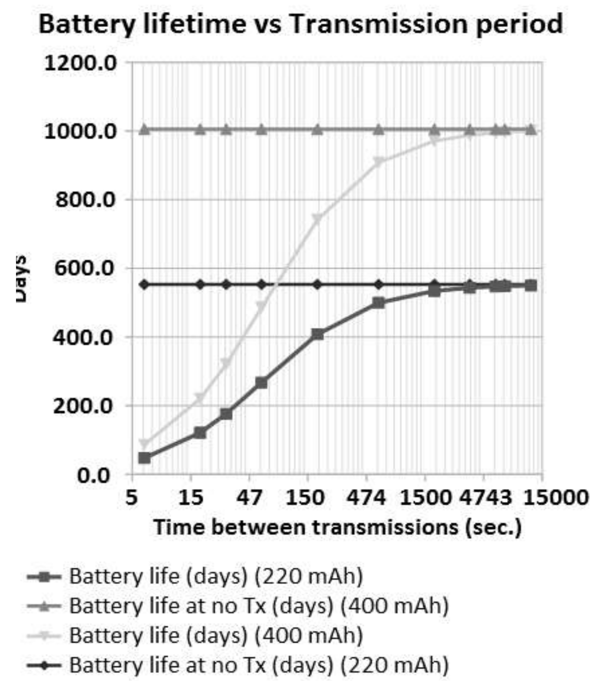

Fig. 9: Estimated battery life time depending on the time between transmissions.

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