An Overview of the IoT Smart Agriculture in Brazil*

Marcelo Oliveira Fernandes - RA 160109[1]
Campinas, Nov. 22nd 2018

***Abstract*— The aim of this article is to present an overview of the IoT applications as far as Smart Agriculture is concerned. It is part of a final project of the discipline "MO629A - Internet of Things", lectured by Prof. Juliana Freitag Borin, of the Institute of Computing of the State University of Campinas - UNICAMP.**

Based on the Brazilian Government study "Internet of Things: an action plan for Brazil", an investigation of existing IoT applications for agriculture was made, taking into consideration known challenges, present network protocol technologies, hardware (sensors and actuators, and regulatory matters).

Finally, an architecture is suggested as an example of a future deployment.

I. INTRODUCTION

The main motivation of this study is to understand the current state of the art of the Internet of Things (IoT) subject with respect upcoming technologies either for academic or industry purposes. Considering this is a very broad subject, this document will restrict its scope to the agriculture environment or Agro 4.0 by initially presenting an overview of the IoT action plan for Brazil followed by an analyze of the associated strategic objectives. Next, the main technical and deployment challenges are discussed. Afterwards, IoT applications and cases both for crop and livestock are shown. Lastly, the future steps are presented along with an example of a likely architecture based on the current trends.

II. OVERVIEW OF THE IoT ACTION PLAN FOR BRAZIL

The Brazilian economy has been seeking for huge investments at least in the last two decades, specially in infrastructure. Unemployment rate was as high as 11.9% in August 2018[1]. However, there is a great expectation that this scenario is about to change. According to McKinsey[2], the potential socioeconomic impact on the productivity of the economy and public services of the IoT was estimated to be up to US$200 billion by 2025, which represents about 10% of the Brazilian GDP of 2016. Therefore in an attempt to promote the sustainable and competitive development of the Brazilian economy, BNDES, in partnership with the Ministry of Science, Technology, Innovation and Communications (MCTIC in Portuguese), sponsored a study for the diagnosis and proposal of the strategic action plan in Internet of Things (IoT) for Brazil[3].

The study has a road map of four major phases and several publications as deliverables. One of them is the "Report of the action plan - Initiatives and Mobilizing Projects"[4]. Among several business opportunities to investigate, four long term subjects were prioritized after being considered the most demanding and with a higher development capacity. Those were Rural, Health, Cities, and Industries, Fig. 1. The former is the chosen vertical to be investigated in this article.

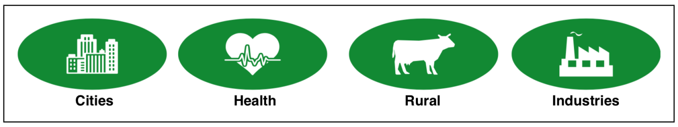


Fig. 1. The four prioritized verticals.

III. THE STRATEGIC OBJECTIVES OF THE RURAL VERTICAL

In the Agro 4.0 Workshop "The Digitalization in the Field", held in August 13th 2018 in São Paulo, Brazil, which was promoted by the Fraunhofer Liaison Office Brazil, it was brought into attention that "in a country that owns farms of the size of Belgium, agribusiness is a mandatory and especially urgent discussion among all the involved actors. Agribusiness accounts for 33% of GDP and 42% of Brazil's total exports, generating around 37% of all jobs nationwide."[5]

One way of encouraging further discussion about this subject is part of the strategic objectives highlighted in the strategic action plan. It aims to increase Brazil's productivity and relevance in the world trade in agricultural products. The following is a suggested pathway to reach the goal of the rural segment.

- Efficient use of natural resources and supplies: Increase the productivity and quality of Brazilian rural production by the use of data.
- Efficient use of machinery: Optimize the use of equipment in the rural environment by the use of IoT.
- Sanitation security: Increase the volume of information and its accuracy in monitoring biological assets.
- Innovation: Promote the adoption of solutions developed locally for environmental challenges.

At the early stage of this research, it has been noticed that **Innovation** is a key effort to orchestrate the remaining strategic objectives and therefore that is going to be the perspective to be assessed herein.

IV. CHALLENGES

According to the Food and Agriculture Organization (FAO), a specialized agency of the United Nations, "Livestock contribute 40% of the global value of agricultural

*This work was not supported by any organization
[1]M. Fernandes is with Institute of Computing State University of Campinas, Av. Albert Einstein, 1251, Campinas/ SP, 13083-852, Brazil m160109@g.unicamp.br

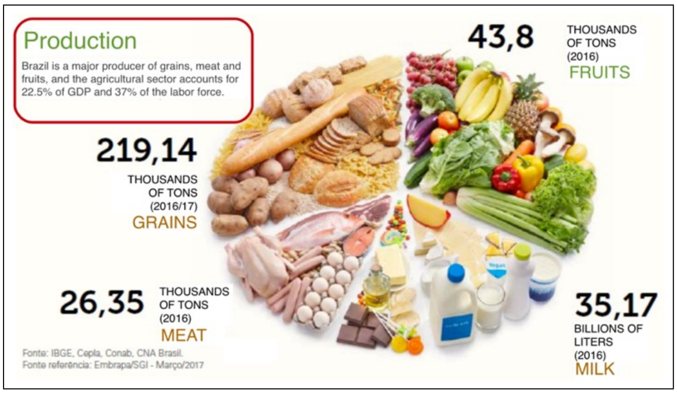


Fig. 2. Food, Fiber and Energy Production.

output and support the livelihoods and food security of almost a 1.3 billion people. The livestock sector is one of the fastest growing parts of the agricultural economy."[40] Furthermore, agriculture in Brazil is the world's 5th largest food producer.[41] A few food production figures from 2016[6] are shown, Fig.2. It is important to mention that no improvement metrics have been defined yet over these production data sample. However, there are known technical challenges to overcome and therefore it will have a positive component as far as end-to-end IoT networks and architectures are concerned. As a consequence a much better productivity performance is expected with IoT deployment.

Vasseur and Dunkels[7] presents technical and no-technical challenges in the development of IoT, which apply not only to the rural environment, but also to the other scenarios as well. First, at the node level, physical size, power consumption and cost of the smart objects are a major concern. Second, at the network level, size of the scale, size of the networks, amount of network nodes and data, untrusted media, addressing, and network management are the ones to be defeated. Third, interoperability and network access (last mile) issues between systems and standards definitions must be beaten.

Non-IoT related rural challenges are also broadly discussed. Barcellos et al.[8] introduce the challenges of pasture beef cattle in the *Cerrado* Region. They talk about the elimination of the practice of extractivism, the equation of supply of quality forage throughout the year, and the integration of grain and meat production systems. In addition to that, de Castro[9] comments about challenges of infrastructure related to inefficient production, as in the case of transport and storage, to aspects of activity productivity and environmental sustainability, as well as guaranteeing income to the producer.

As far as agriculture is concerned, Jorge and Inamasu[10] talk about the existence of several challenges such as highlighting the monitoring of natural resources, environment, atmosphere, hyperspectral imaging, observations of rivers and lakes, as well as the imaging of agricultural practices and land use. Likewise, Massruhá et al.[11] refer to challenges that must be overcome to achieve the desired increase

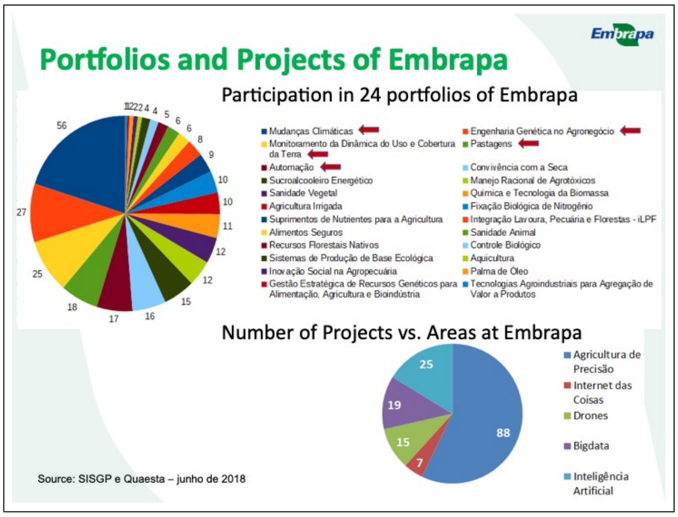


Fig. 3. Portfolio and Projects of Embrapa.

in productivity: heterogeneities inherent in the agricultural production ecosystem (biological, chemical and physical systems); extreme events of the atmosphere; large geospatial dispersion; food safety and food safety requirements, in addition to the constraints of agriculture.

The situations shown above are likely to be solved with the adoption of IoT, as a facilitator to address each and every problem properly. It should not be dealt individually, rather it must be done as a common goal to be reached globally and openly. Regulations and standardizations are required and must be driven to benefit end-users and not the interest of just a few global companies. Cartels must not be allowed. Research and Development is a key success factor for the IoT endeavour.

The Brazilian Agricultural Research Corporation (Embrapa - Portuguese: Empresa Brasileira de Pesquisa Agropecuária)[12], which was founded on April 26, 1973, and is under the aegis of the Brazilian Ministry of Agriculture, Livestock, and Food Supply, has an important R&D role in the rural IoT scenario. Embrapa mediates the government strategy with the industry requirements regarding farming. As of June 2018[6], Emprapa was engaged in 24 portfolios. It is worth mentioning that 154 projects are IoT related and they were grouped in 5 different areas, as depicted in Fig. 3. The Embrapa Agriculture Informatics division develops projects in information technology applied to agribusiness, and works in the areas of software engineering, scientific computing, communication technology, bioinformatics, and agroclimatology. Some applications are presented next.

V. IoT Architecture for Agriculture

Minerva et al.[14] define IoT as "a network that connects uniquely identifiable "Things" to the Internet. The "Things" have sensing/actuation and potential programmability capabilities. Through the exploitation of unique identification and sensing, information about the "Thing" can be collected and the state of the "Thing" can be changed from anywhere, anytime, by anything." On top of that, ITU[15] adds to the

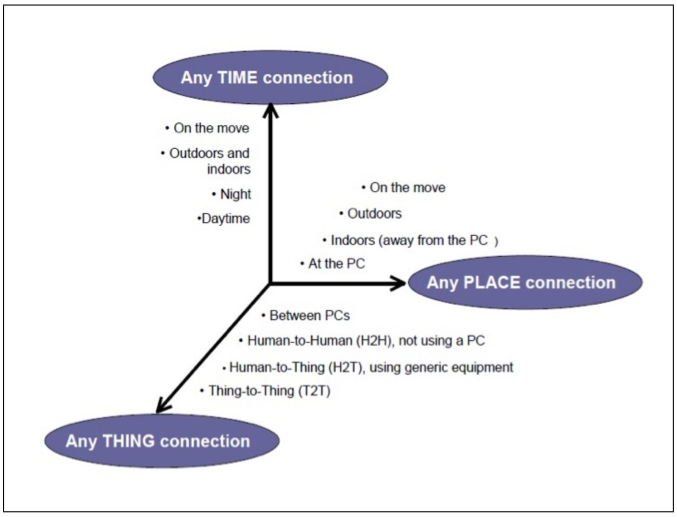


Fig. 4. ITU definition of IoT.

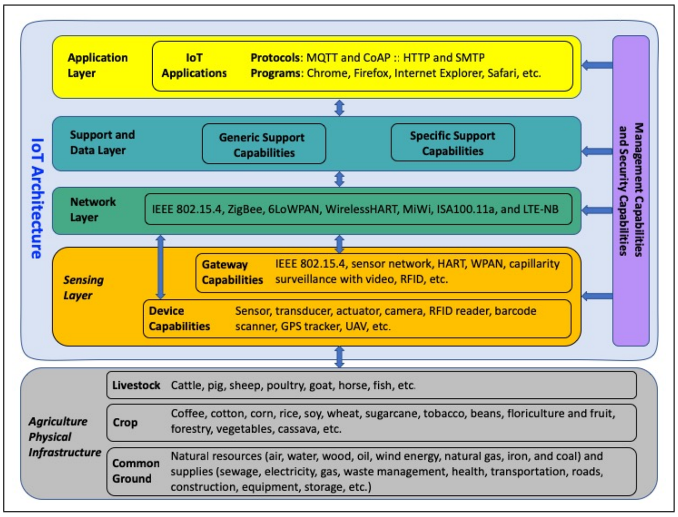


Fig. 5. Technology integration of IoT solutions for rural areas.

definition of IoT as a network that is "available anywhere, anytime, by anything and anyone", Fig. 4.

Despite the fact that IoT should be considered a relatively new matter of the past 10 years or so, there already are several application currently in use that partially matches the above definitions. As the technology evolves these applications are merged to each other as pieces of a larger puzzle. In order to help understanding what is going to be presented next, **Agriculture (Farming)** applications will be divided into **Crop** and **Livestock** segments. Based on a IoT reference model proposed by ITU[15 16], a typical rural IoT architecture is suggested in Fig.5 and it is composed of sensing, network, support and data, and application layers, along with its management and security capabilities, to interact directly with the physical infrastructure of the rural area.

First, the rural physical infrastructure is composed by multiple common ground items such as natural resources (i.e. air, water, wood, oil, wind energy, natural gas, iron, and coal) and supplies (sewage, electricity, gas, waste management, health, transportation, roads, construction, equipment, storage, etc.). In addition to that, the crop cultures are extremely diverse in Brazil, specially due to the large territorial extension and climate, and they are associated to any, but not limited to, the following productions: coffee, cotton, corn, rice, soy, wheat, sugarcane, tobacco, beans, floriculture and fruit, forestry, vegetables and cassava, to mention a few. Moreover, the Brazilian livestock takes care of the end-to-end production chain to raise cattle, pig, sheep, poultry, goat, horse, fish, etc. These are examples of existing elements that should be monitored by the IoT system in order to enhance productivity, management and therefore agriculture revenue.

Second, the sensing layer is responsible to make the interface between the physical infrastructure and the network layer. On one hand, it uses outdoor sensors and actuators to interact with the existing elements or things. The sensors are able to collect data either from the ground, i.e. moisture, rain and water flow, soil temperature, conductivity, and salinity; or from the environment, i.e. air humidity, air temperature, atmospheric pressure, wind speed, solar radiation, and rain. Besides, multispectral sensors, cameras, microphones, transducer, RFID reader, barcode scanner, GPS tracker, etc. are also used. On the other hand, gathered data from sensor have to be handed in to the network layer. This communication feature is also embedded in the sensors.

In order to comply with the previous statements and considering hardware and software development, the sensor design, Fig.6, should take into consideration:

- **Sizing:** sensor must be tiny enough to be in direct contact or as close as possible to the reference element to collect data accurately;
- **Power consumption:** these sensors may be monitoring mobile or fixed elements in the field for a lifetime of years (10 yrs), far from wired infrastructures, therefore standard lithium cell batteries, such as watch/ coin battery or button cell, are the preferred power supply, as opposed to other ready available sources of energy (i.e. larger batteries, bank of batteries, power outlet, solar panel, etc.);

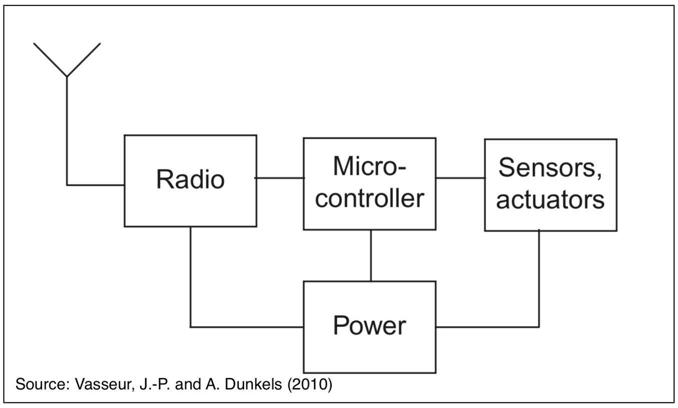
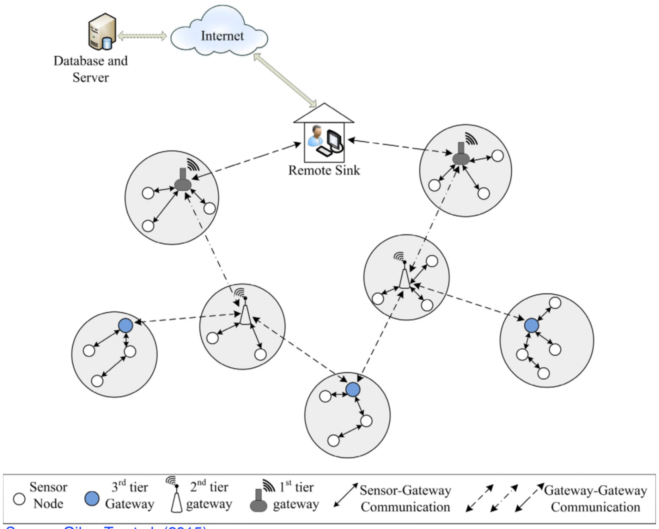


Fig. 6. The hardware architecture of a wireless smart object.

- **Communication:** sensors and actuators, also known as nodes, transmit/ receive data through Wireless Sensor

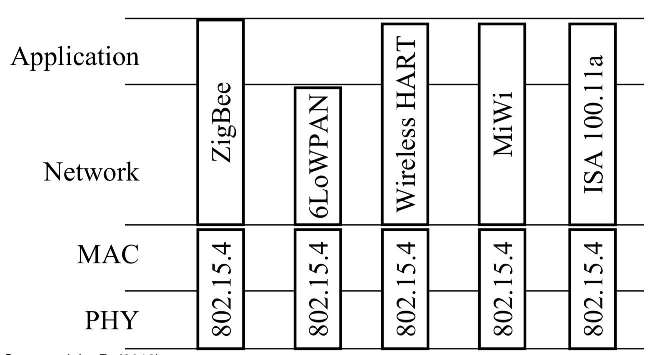


Source: Ojha, T., et al. (2015)

Fig. 7. Sensor nodes scattered in a sensor field.

Networks (WSN)[17], at a low-data-rate (maximum of 250,000 bits/s), a long-distance-range (few tens of meters), and a maximum output power of 1mW. In this environment, nodes interact with gateways (sink) on a many-to-one communication pattern fashion[7] once in a while, otherwise they stay on a sleep mode to save power, Fig. 7.

Third, the network layer is responsible for network connectivity and the transport of IoT service and application specific data information, based upon the TCP/IP reference model. The physical and MAC communication standard is the IEEE 802.15.4 (Fig.8), which is a standard radio technology for low-power, low-data-rate applications. Unlicensed frequency bandwidth at sub-gigahertz is available. While the network standard has multiple developments[18], i.e. ZigBee, 6LoWPAN, WirelessHART, MiWi, and ISA100.11a. There are many technologies available for agriculture applications[19 20], including the 5G LTE Narrow Band (LTE-NB) which is expected late 2020. Non-exhaustive comparison among several existing technologies are depicted in Figures 9 and 10.



Source: Jain, R. (2016)

Fig. 8. Examples of low power radio stacks built on IEEE 802.15.4.

	WIFI	BLE	ZIGBEE Pro	SIGFOX	LoRa	LTE-M/(eMTC) (Rel. 13)	EC-GSM (Rel. 13)	NB-IoT (Rel. 13)	5G (targets)
Coverage Area	17–30+ (meters)	1–10+ (meters)	1–100+ (meters)	<12km 160 dB	< 10km 157 dB	< 10km 156 dB	< 15km 164 dB	<15km 164 dB	<12km 160 dB
Spectrum Bandwidth	2.4G 802.11	2.4G 802.15.1	2.4G 802.15.4	Unlicensed 900MHz 100Hz	Unlicensed 900MHz <500kHz	Licensed 7-900MHz 1.4 MHz shared	Licensed 8-900MHz shared	Licensed 7-900MHz 200 kHz shared	Licensed 7-900MHz shared
Rate	150Mbps+	1Mbps	250kbps	<100bps	<10 kbps	< 1 Mbps	10kbps	<50 kbps	< 1 Mbps
Terminal Cost	4.00$ (2016)	4.00$ (2016)	3.00$ (2016)	4.00$ (2015) 2.64$ (2020)	4.00$ (2015) 2.64$ (2020)	5.00$ (2015) 3.30$ (2020)	4.5$ (2015) 2.97$ (2020)	4$ (2015) 2-3$ (2020)	<$2
Network Reforming	None	None	None	Large	Large	Small	Moderate (LTE reuse)	Small to Moderate	Requires 5G NWs

Source: Yu, C., et al. (2017).

Fig. 9. Comparison of IoT technologies (1).

Parameters	WiFi	WiMAX	LR-WPAN	Mobile communication	Bluetooth	LoRa
Standard	IEEE 802.11 a/c/b/d/g/n	IEEE 802.16	IEEE 802.15.4 (ZigBee)	2G-GSM, CDMA 3G-UMTS, CDMA2000 4G-LTE	IEEE 802.15.1	LoRaWAN R1.0
Frequency band	5–60 GHz	2–66 GHz	868/915 MHz, 2.4 GHz	865 MHz, 2.4 GHz	2.4 GHz	868/900 MHz
Data rate	1 Mb/s–6.75 Gb/s	1 Mb/s–1 Gb/s (Fixed) 50–100 Mb/s (mobile)	40–250 Kb/s	2G: 50–100 kb/s 3G: 200 kb/s 4G: 0.1–1 Gb/s	1–24 Mb/s	0.3–50 Kb/s
Transmission range	20–100 m	< 50Km	10–20 m	Entire cellular area	8–10 m	< 30 Km
Energy consumption	High	Medium	Low	Medium	Bluetooth: Medium BLE: Very Low	Very Low
Cost	High	High	Low	Medium	Low	High

Source: Ray, P. P. (2016)

Fig. 10. Comparison of IoT technologies (2).

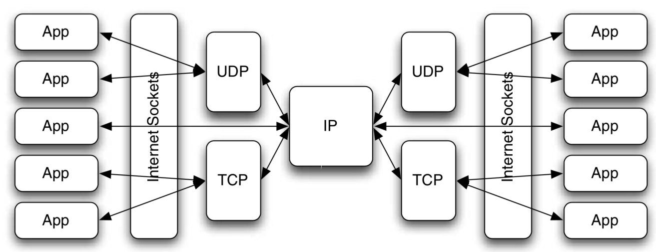
Forth, support and data layer is in charge of generic and specific data processing or data storage. Besides, it provides different support functions to different IoT applications[21]. Applications process communication occurs through Internet sockets, as shown in Fig.11.

Fifth, the application layer handles the IoT applications. Well known application can either be:

- **Protocols:** HyperText Transfer Protocol (HTTP), Simple Mail Transfer Protocol (SMTP); or
- **Programs:** Chrome, Firefox, Internet Explorer, Safari, etc.

While IoT standard protocols are currently:

- **Message Queuing Telemetry Transport (MQTT)[22]:** an ISO standard (ISO/IEC PRF 20922) publish-subscribe-based messaging protocol. It works on top of the TCP/IP protocol;



Source: Shelby, Z. and C. Bormann (2011)

Fig. 11. Transport protocols

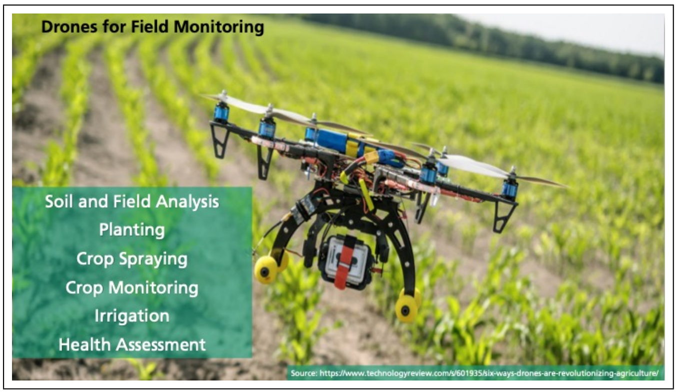


Fig. 12. Precision Agriculture.

- **Constrained Application Protocol (CoAP)**[23]**:** known as "the Web of Things Protocol". It has a compact 4-byte header and supports UDP (may be used on top of TCP and SMS). It provides strong DTLS security and asynchronous subscription. Semantically aligned with HTTP.

They both are open source standards and suited to constrained environments. They allow asynchronous communication and run on IP.

Finally, the management capabilities and security capabilities layer is responsible to orchestrate the management and the security of the entire system[15].

- **Management:** it covers the traditional fault, configuration, accounting, performance and security, i.e. fault management, configuration management, accounting management, performance management and security management, device management, local network topology management, traffic and congestion management, etc.

Fig. 13. Mango Detection.

- **Security:** it is segregated in generic security capabilities and specific security capabilities.
  - at the application layer: authorization, authentication, application data confidentiality and integrity protection, privacy protection, security audit and anti-virus;
  - at the network layer: authorization, authentication, use data and signalling data confidentiality, and signalling integrity protection;
  - at the device layer: authentication, authorization, device integrity validation, access control, data confidentiality and integrity protection.

VI. IoT AGRICULTURE APPLICATIONS

Generally speaking, agriculture applications aims to optimize production, enhance business revenue and profitability, improve the use of resources (i.e. natural, equipment, and human), minimize expenses, eliminate and/or reduce the effect of plagues and diseases, and create a controlled environment in near real time, anywhere, anytime. The following is a short description of crop and livestock applications.

A. PRECISION CROPS

The literature presents extensive national and overseas applications of precision crops[6, 24, 25, 26, 27]. It takes into consideration large coverage areas, climate conditions, biodiversity and environment aspects.

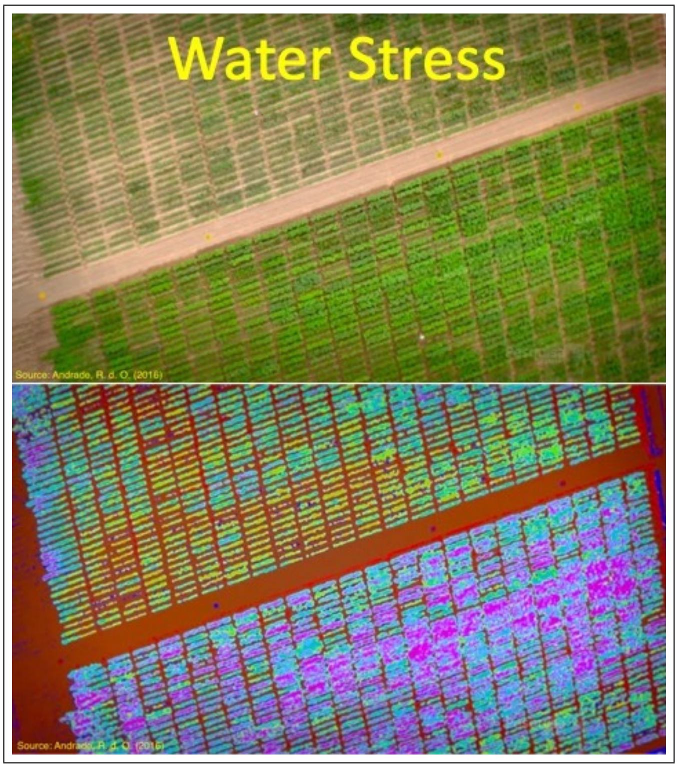


Fig. 14. Water stress analysis. Top: common image. Bottom: infrared lens.

Therefore, the broad range of the required field applications are far from being fully exploit given the number of likely possibilities, meaning "problems or pain" to address.

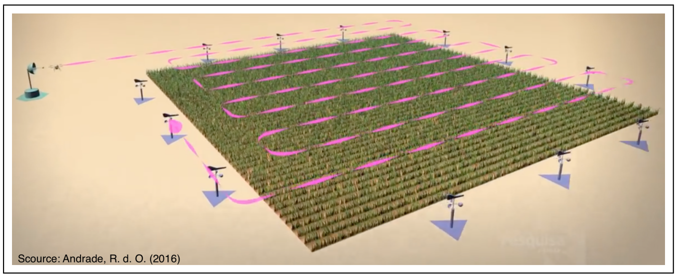


Fig. 15. Fertilization made by an Unmanned Aerial Vehicle (UAV).

Fig. 17. Left: Cattle collars. Right: Node with solar cell on top.

For the time being, the current research investigated the following ones:

- Use of sensors[27];
- Autonomous machines[28](Fig.12) and GPS system;
- Monitoring of plant needs;
- Available water in soil and rainfall and subsequent performance (irrigation);
- Computer vision[10 29 30]:
  - Harvesting (Fig.13);
  - Irrigation and water management (Fig.14);
  - Weed removal and pest control (Fig.15).

B. *PRECISION LIVESTOCK*

Likewise, precision livestock has been researched for quite some time[6 25 31 32 33 38]. Next, one can see some of the searched applications (Fig.16):

- Precision handling and nutrition traceability;
- Monitoring the herd;
- Collar: health monitoring (movement, leisure and rumination) and virtual fence[36] (Fig.17);
- Earrings: complete technical log of the animal (date of birth, age, vaccination portfolio, diseases and its georeferenced location).

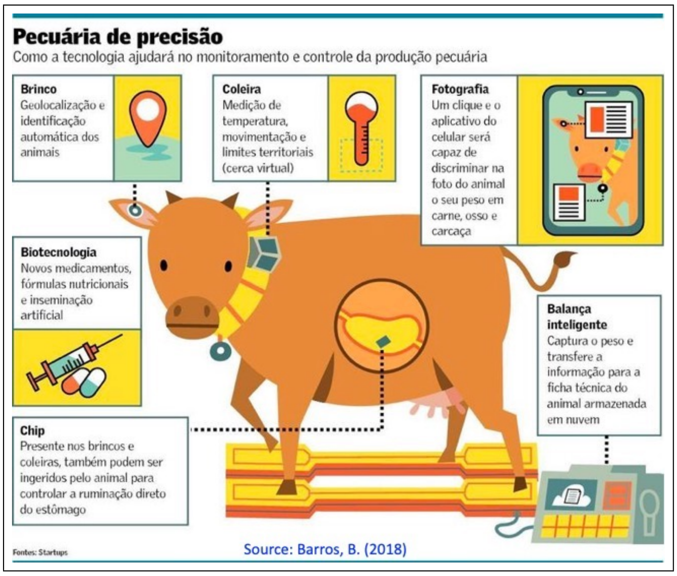


Fig. 16. Precision livestock applications (Portuguese).

- Intelligent scales: the animal can be weight while walking on the equipment[37];
- Chips: monitor the temperature and movement of the animal[34];
- Carcass photography: algorithms that calculate the weight of the carcass from a 3D image[6], Fig.18.

VII. OVER THE FENCE

Much of the current work in this field of expertise has been done by agriculture start ups, also known as “agtechs”. It has been said[39] that “between 2016 and 2018, Brazil has started 110 companies focused on the sector. They were 76, and now raised to 186. Of these, 30% work with solutions for beef cattle and 20% for dairy products (some work on both ends)”.

It is a clear sign that this subject has a great potential for profitable businesses, but it also demonstrates lack of a mature technology. It seeks for regulation and there are still big technical and non-technical challenges to overcome. Maybe it explains why big global companies are also facing issues and postponing marketing their own approaches. Therefore, it is a golden R&D opportunity to explore new ideas, concepts and developments. It is worth remembering that there are solid technologies out there to support part of the system in the architecture, however questions associated to interoperability, telecommunications last mile provisioning, regulatory, and sponsorship still remain.

Proof of Concepts (PoC’s) should be considerably widespread to validate existing and new trends. Open source solutions must be mandatory. Besides, considering the deployment of disruptive technologies, there will be a great demand of human resources with very specific technical skills. Therefore, it is also a concern that should be addressed.

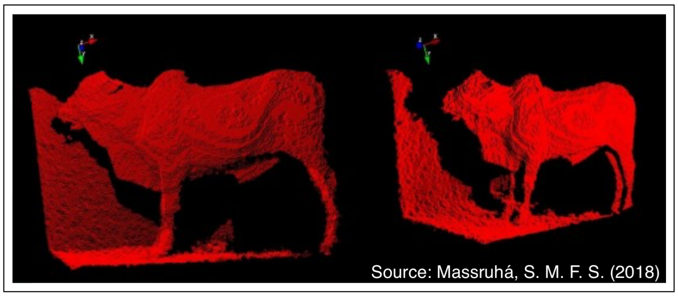


Fig. 18. 3-D image obtained by a RGB-D camera in a Nelore cattle.

A lot of effort and hope has been put on 5G as an infrastructure mean to support IoT. It is true, however it is important to bear in mind its road map. IMT-2020 Specifications should be available by late 2020. It will take some time to actually have the associated hardware and software designed, produced and available for deployment. On top of that, the Telecommunications Service Providers (TSP's) have to go through acquisition and deployment process, which usually take quite some time. It means that an interim solution must be considered. Assuming latency is not a big deal for agriculture application, one should consider satellite communications due to their inherit footprint and service availability in Brazil[42].

VIII. CONCLUSIONS

Researches lead to deeper analyses which require knowledge of multiple disciplines from Electrical Engineering and Computing, more specifically the ones related to IoT, mathematics models, artificial intelligence, image processing, computer vision, big data, machine learning, and mobile robotics, to mention a few, in order to deal with other correlated subjects such as agricultural models, climate, growth, production, irrigation, fertilization, etc. Therefore it is clear that there is no single solution or one-size-fits-all solution. Smart agriculture is a very huge subject and it requires a joint effort to evolve.

An overview of the agriculture system in the light of IoT has been presented. Starting from motivation, followed by challenges, and then IoT for agriculture was discussed. An architecture has been proposed, along with several existing application for both crop and livestock were presented. Finally, some insights were shown for further discussion.

Indeed there is a great prospering opportunity ahead to explore R&D demands and the industry services. Innovation is key to make "things" work together.

REFERENCES

[1] IBGE (2018). Pesquisa Nacional por Amostra de Domicílios Contínua - PNAD Contínua; Taxa de desocupação das pessoas de 14 anos ou mais, jun-jul-ago 2018. Retrieved 12 Nov 2018, from https://www.ibge.gov.br/estatisticas-novoportal/sociais/educacao/9171-pesquisa-nacional-por-amostra-de-domicilios-continua-mensal.html?edicao=22655&t=destaques.

[2] Marques, F. (2017). O Brasil da Internet das Coisas. Revista Pesquisa FAPESP.Retrieved 06 Nov 201, from https://goo.gl/DtXDTU.

[3] BNDES (2017). Estudo "Internet das Coisas: um plano de ação para o Brasil". Retrieved 29 Oct 2018, from https://goo.gl/y9A2vn. Accessed on 06 Nov 2018.

[4] BNDES (2017). Produto 8: Relatório do Plano de Ação Iniciativas e Projetos Mobilizadores, BNDES. Retrieved 13 Nov 2018, from https://www.bndes.gov.br/wps/wcm/connect/site/269bc780-8cdb-4b9b-a297-53955103d4c5/relatorio-final-plano-de-acao-produto-8-alterado.pdf?MOD=AJPERES&CVID=m0jDUok.

[5] Fraunhofer (2018)."Agro 4.0: Experts discuss advances in digitizing the field." Retrieved 13 Nov 2018, from https://www.brazil.fraunhofer.com/en/news$_events/news/agro-4-0--experts-discuss-advances-in-digitalization-in-the-fiel.html$.

[6] Massruhá, S. M. F. S. (2018). IoT na Embrapa: BNDES Estudo Nacional de IoT. Retrieved 13 Nov 2018, from https://www.bndes.gov.br/arquivos/iot/04-embrapa.pdf.

[7] Vasseur, J.-P. and A. Dunkels (2010). Interconnecting smart objects with IP: The next internet, Morgan Kaufmann.

[8] Barcellos, A. O., et al. (2001). "Desafios da pecuaria de corte a pasto na regiao do cerrado." Embrapa Cerrados-Documentos (INFOTECA-E).

[9] de Castro, C. N. (2014). A agropecuária na região Centro-Oeste: limitações ao desenvolvimento e desafios futuros, Texto para Discussão, Instituto de Pesquisa Econômica Aplicada (IPEA).

[10] Jorge, L. A. d. C. and R. Y. Inamasu (2014). Uso de veículos aéreos não tripulados (VANT) em agricultura de precisão. Embrapa Instrumentação-Capítulo em livro científico (ALICE).

[11] Massruhá, S. M. F. S., et al. (2014)."Os novos desafios e oportunidades das tecnologias da informação e da comunicação na agricultura (AgroTIC)." Embrapa Informática Agropecuária-Capítulo em livro científico (ALICE).

[12] EMBRAPA. "Brazilian Agricultural Research Corporation." Retrieved 14 Nov 2018, from https://www.embrapa.br/en/international.

[13] Minerva, R., et al. (2015). "Towards a definition of the Internet of Things (IoT)." IEEE Internet Initiative 1: 1-86.

[14] ITU-T (2012). Recommendation ITU-T Y.2060. Overview of the Internet of Things. ITU-T Study Group 13.

[15] BNDES (2018). Cartilha de Cidades, BNDES.

[16] Akyildiz, I. F., et al. (2002). "Wireless sensor networks: a survey." Computer Networks 38(4): 393-422.

[17] Jain, R. (2016). Wireless Protocols for IoT Part II: IEEE 802.15.4 Wireless Personal. Area Network.

[18] Yu, C., et al. (2017). "Uplink scheduling and link adaptation for narrowband Internet of Things systems." IEEE Access 5: 1724-1734.

[19] Ray, P. P. (2016)."A survey of IoT cloud platforms." Future Computing and Informatics Journal 1(1-2): 35-46.

[20] Shelby, Z. and C. Bormann (2011). 6LoWPAN: The wireless embedded Internet, John Wiley & Sons.

[21] HiveMQ. "MQTT Essentials Part 2: Publish & Subscribe." Retrieved 20 Nov 2018, from http://www.hivemq.com/.

[22] Shelby, Z. (2014). "CoAP: The Web of Things Protocol. ARM IoT Tutorial."

[23] Santos, T. T., et al. (2017). Automatic grape bunch detection in vineyards based on affordable 3D phenotyping using a consumer webcam, In: CONGRESSO BRASILEIRO DE AGROINFORMÁTICA, 11., 2017, Campinas. Ciência de ...

[24] Santos, T. T. (2017). Perspectivas de Internet das Coisas no ambiente rural. Conference: Hay Campo para las TICs. Cenário do uso de IoT no campo e perspectivas.

[25] Sa, I., et al. (2016). "Deepfruits: A fruit detection system using deep neural networks." Sensors (Basel) 16(8): 1222.

[26] Ojha, T., et al. (2015). "Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges." Computers and Electronics in Agriculture 118: 66-84.

[27] Michal Mazur, P. (2016, July 20, 2016). "Six Ways Drones Are Revolutionizing Agriculture - MIT Technology Review." Retrieved 21 Nov 2018, from https://www.technologyreview.com/s/601935/six-ways-drones-are-revolutionizing-agriculture/.

[28] Andrade, R. d. O. (2016). Drones sobre o campo: Avanços tecnológicos ampliam as possibilidades do uso de aeronaves não tripuladas na agricultura. Revista Pesquisa FAPESP.

[29] Santos, T. T. (2015). Detecção automática de bagas de café em imagens de campo, In: CONGRESSO BRASILEIRO DE AGROINFORMÁTICA, 10., 2015, Ponta Grossa. Uso de VANTs e sensores para avanços no agronegócio: anais. Ponta Grossa: Universidade Estadual de Ponta Grossa, 2015.

[30] Corke, P., et al. (2010). "Environmental wireless sensor networks." Proceedings of the IEEE 98(11): 1903-1917.

[31] Ambrosio, J., et al. (2015). Learning About Animals and Their Social Behaviors for Smart Livestock Monitoring. International Internet of Things Summit, Springer.

[32] Beng, L. T., et al. (2016). Field testing of IoT devices for livestock monitoring using Wireless Sensor Network, near field communication and Wireless Power Transfer. Technologies for Sustainability (SusTech), 2016 IEEE Conference on, IEEE.

[33] Ciira, W. M. (2017). IoT at the GrassrootsExploring the Use of Sensors for Livestock Monitoring, IST-Africa 2017 Conference Proceedings.

[34] Kim, Y.-B. and D.-O. Choi (2014). "Design of Business Management System for Livestock Pens Based of IoT." Journal of the Korea Entertainment Industry Association (JKEIA) 8(1): 207-216.

[35] Koompairojn, S., et al. (2017). Smart tag tracking for livestock farming. Ubi-media Computing and Workshops (Ubi-Media), 2017 10th International Conference on, IEEE.

[36] Vaughan, J., et al. (2017). Floor sensors of animal weight and gait for precision livestock farming. SENSORS, 2017 IEEE, IEEE.

[37] Zhang, J., et al. (2016). "Design and development of IOT monitoring equipment for open livestock environment." International Journal of Simulation: Systems, Science and Technology 17(26).

[38] Barros, B. (2018). O olho do dono, que engorda o boi, agora é digital. Valor Agronegcio.

[39] Nations, T. F. a. A. O. F. o. t. U. "Animal production: FAO's role in animal production." Retrieved 10 Nov 2018, from http://www.fao.org/animal-production/en.

[40] Brasil, G. d. (2018, 08 Jun 2018). "Agricultura familiar do Brasil é 8ª maior produtora de alimentos do mundo." Retrieved 22 Nov 2018, from http://www.brasil.gov.br/noticias/economia-e-financas/2018/06/agricultura-familiar-brasileira-e-a-8a-maior-produtora-de-alimentos-do-mundo.

[41] Brasil, H. d. "Agronegócio." Retrieved 22 Nov 2018, from http://www.hughes.com.br/mercados/agronegocio.