An NFC-LoRa Connectivity Tandem as IoT bridge to Improve Safety in Food and Feed Delivery

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***Abstract*—Multiple major food crises have plagued the world in the last decades. In many cases, tracing the original contamination back to its source proves to be a difficult challenge due to no tracing mechanism being in place for food and feed past the production facility. Introducing a system that can trace delivery between the production site and the silo addresses this problem. For this purpose, a novel approach to identify silos and communicate this information with the bulk trailer is introduced. We propose an approach using an NFC-LoRa tandem to fulfill the contradicting communication requirements. We discuss state of the art technologies and elaborate our technical choices. A functional prototype was built and validated.**

***Index Terms*—NFC, LoRa, agriculture, food safety**

I. Introduction

Safety in the agri-food chain is a key element for public health and trust. Controversies regarding this subject appear in the press on a regular basis. In Western Europe alone, there have been multiple major food crises in the last decades (e.g. Dioxin affair [1], EHEC outbreak [2] and Fipronil eggs contamination [3]). Animal feed or human food producers put enormous efforts in establishing reliable mechanisms to trace the commodities up to the moment they leave the production site. However, once the bulk leaves the production site, no further tracking mechanisms exist. Practice shows bulk goods end up in an incorrect silo occasionally. Erroneous deliveries can create, if detected, significant costs for the customer. The delivered bulk has to be destroyed and the silo needs to be sanitized. Even worse, if undetected, it could have a significant impact on the food-chain and put the health of animals and people at risk.

Introducing a fully automated tracing system can guarantee safety for the food chain and avoid unnecessary costs. Furthermore, a contamination (like dioxin or fipronil) could be traced back to their source much more effectively, minimizing the consequences on the food chain and possibly averting a crisis all together. Such a system requires information at the trailer side on which kind food or feed it is transporting and which silo it has to be loaded in. This data-transfer has to happen at the production site. The bulk trailer is compartmentalized adding to the complexity of tracing each good individually. Once the trailer arrives at the customer premises, a verification needs to happen on the silo's identity. Only when the correct silo is identified, the corresponding bulk compartment can be discharged into the silo. For this purpose, we propose an Internet of Things (IoT) based solution that can communicate between bulk trailer and silo. The challenge in the technological exploration occurred due to the following two conflicting requirements: 1) Silos can be as close as 10 cm together. False detection of secondary silos must be avoided at all costs and 2) the trailer can be parked up to 100 m away from the silo with the Line-of-Sight (LoS) potentially being obstructed by e.g. trees, concrete walls and metal. This distance has to be covered by a wireless link.

While many IoT communication technologies exist, none alone offer the required service. Hence, our solutions present as daisy-chain of robust communication technologies to guarantee connection between silo and trailer. A smart IoT-device gets attached to the silo and is responsible for silo identification on the one hand, and forwarding the silo identification to the bulk trailer on the other hand. This way the IoT-device forms a bridge between silo and bulk trailer. For simple, robust and reliable silo identification, Near Field Communication (NFC) is implemented on the IoT-bridge and the silo is equipped with an NFC-tag. The chosen technology to communicate between the IoT-bridge and the bulk trailer is Long Range (LoRa) due to its ability assure long-range

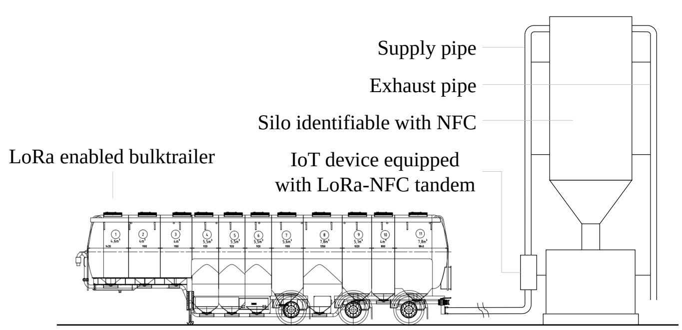

Fig. 1: The trailer is connected to the silo by means of a filling tube. This tube may cover long distances. The IoT-device is connected to one of the pipes equipped with an NFC-tag. Only when the correct silo is detected, the food from the corresponding compartment can be discharged into the silo.

connection in extreme environments. Fig 1 illustrates the setup.

This paper summarizes the state of the art technologies to identify the silo and to communicate between the IoT-bridge and trailer. Next, we elaborate on the selected technologies. Furthermore we discuss our experimental setup, draw conclusions and summarize future work.

II. Technology Overview

The smart device requires two technologies, each with their own, sometimes conflicting, requirements. These requirements together with possible technological solutions are discussed in this section.

A. Unambiguous Silo Detection

The silo requires a Unique Identifier (UID) that is linked to its location, owner and the kind of substance it contains. This implies that an identifier has to be attached to the silo that securely links the silo to this information. Critically, the identification must be low-cost, secure and robust against dust, dirt and environmental influences like extreme weather conditions.

The most simple technology that can be used is Quick Response (QR) codes [4]. A QR code is a matrix barcode that contains the identifier. QR codes are cost-effective, straightforward to attach to the silo and use. However, dust and dirt can render them unreadable, they can easily be vandalized and they are accessible to anyone. Most importantly, user error cannot be eliminated completely, an absentminded driver could easily scan the wrong QR code from a nearby silo.

Another common UID technology is touch memory [5]. These devices consist of a memory chip enclosed in a thick stainless steel coin-like enclosure. The enclosure is extremely robust against scratches and corrosion. However, it requires a physical connection making it sensitive to dirt and dust.

A contactless option is Radio-Frequency Identification (RFID). This technology leverages on electromagnetic fields to detect tags in a reader's proximity. Numerous standards and implementations exist, each aimed at specific applications [6]. Leveraging RFID tags for identification fulfills all requirements but one. Most RFID standards do not restrict the detection range to maximum 10 cm. However, an extension of the RFID specification, called NFC, is aimed specifically at short range applications such as identification and authentication. NFC-readers are capable of detecting tags at a distance less than 10 cm allowing unambiguous silo detection. Moreover, tags covered in dirt can still be detected due to the contactless readout. Finally, the tags attached to the silo are extremely low-cost allowing for large scale cost efficient installation for customers. These combined advantages make NFC an excellent technology for this application and hence our preferred solution.

B. Robust Long Range Connectivity

Once the silo has been identified, the UID has to be communicated to the bulk trailer. This requires Very little throughput yet at long range and connection needs to be guaranteed in environments where LoS may be obstructed by trees, metal and concrete.

We evaluate Zigbee Pro, Sigfox and LoRa as possible communication technologies for this link. An overview of the most relevant specifications for these standards is given in Table I.

The Sigfox network offers an end-to-end Low Power Wide Area Network (LPWAN) solution focusing on extended range and low power transmissions and thus allowing long battery life [7]. A network operator provides coverage using proprietary base stations. While distances up to 50 km can be covered, more remote areas still are not sufficiently coved for this application [8]. Besides, due to the proprietary nature of the technology, no private networks can be deployed and hence, connectivity is only offered as a service [9].

Zigbee PRO is a an IEEE 802.15.4 based specification offering the possibility to deploy ad hoc mesh networks [10]. It supports communication in the 2.4 GHz and sub-GHz band. Sub-GHz transmissions offer longer range up to 1 km. However, Zigbee Pro modems (e.g. an XBee Pro) come at a very high cost (€75).

Finally, there is Long Range Wide Area Network (LoRaWAN) [11], another LPWAN solution. It employs Chrip Spread Spectrum (CSS) as a modulation technique with a variable Spreading Factor (SF). Increasing the SF will increase the range at the cost of data rate, time on air and power consumption. Network coverage is provided by operators, yet there are also community sourced LoRaWAN networks, for example The Things Network (TTN). Many modems (e.g. SX1276 or RN2483) allow communicating in a P2P fashion employing just the LoRa physical layer. This increases deployment flexibility, eliminates a possible subscription cost and the need for the application to be within the network coverage zone. Modems are much more inexpensive (€5-10) than Zigbee Pro modems. It assures connection in extreme environments well beyond our 100 m requirement as described in our related work [12].

III. Setup and Validation

A functional prototype was built using off-the-shelf components. The prototype's functionality is illustrated in Fig. 2. A LoRa-receiver module on the trailer communicates with the trailers control system. The chosen LoRa-modem is the SX1276 [13] because of its low cost and high availability. The NFC-reader and LoRa connectivity are controlled by a simple microcontroller. Our setup used the ATmega328P [14] because of its excellent documentation and community support. The NFC-reader is based on NXP's CLRC663. The chip is a multi-protocol NFC-frontend ensuring compatibility with various kinds of tags that may be used in different geographical regions [15]. In most cases, the silos will be equipped with on-metal tags. No other permanent changes need to be made to the silo. The IoT-bridge first detects the UID programmed onto the NFC-tag. The UID is sent to the bulk trailer using the LoRa connection. The bulk trailer will automatically allow the corresponding load for the silo to be discharged. If no

	Zigbee Pro	Sigfox	LoRa
Deployment model	Ad hoc	Nationwide with no roaming	Ad hoc
Data rate	250 kb/s (2.4 GHz) and 20 kb/s (Sub-GHz)	100 bps (UL), 600 bps (DL)	0.3 - 37.5 kbps
Range (theoretical)	Up to 1 km	Up to 50 km (rural)	Up to 15 km (rural)
Frequency band	2.4 GHz ISM and Sub-GHz ISM	Sub-GHz ISM	Sub-GHz ISM
Topology	Mesh	Star	Point-to-Point (P2P)

TABLE I: Comparison of wireless communication candidates

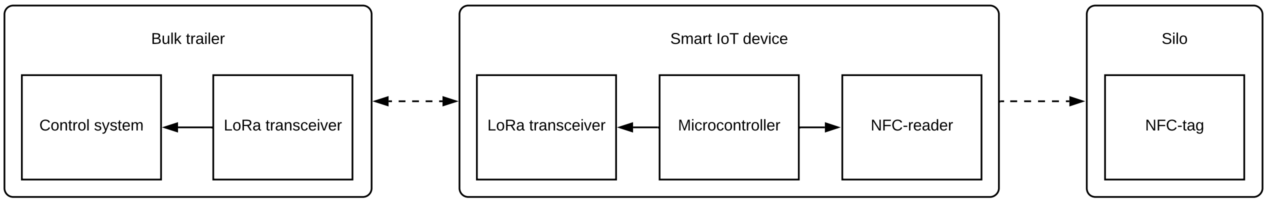

Fig. 2: A schematic overview of the communication tandem. The IoT-bridge will detect the silo's UID with NFC and forward it to the trailer by a P2P connection. The trailer's control system will release the corresponding load for the silo.

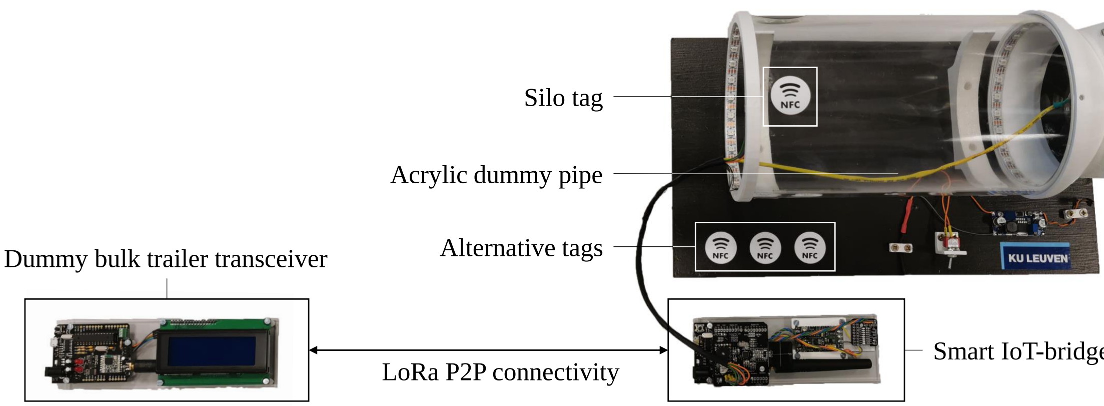

Fig. 3: The practical setup is depicted here. The picture shows the acrylic tube emulating the fill or exhaustpipe of the silo. An on-metal NFC-tag programmed with its UID is attached to the tube. A few alternative NFC-tags with incorrect UID are provided. The prototypeIoT-bridge and bulk trailer transceiver communicating with a LoRa P2P are also depicted. The bulk trailer transceiver is equipped with an LCD-screen. The LCD-screen displays information regarding the detected tag and if the bulk load may be discharged.

corresponding silo is detected, no bulk will be discharged, thus ensuring full traceability of the bulk. Fig. 3 shows a picture of our demo setup. An acrylic pipe emulates the silo on which an NFC-tag is attached. Multiple incorrect tags are provided on the setup to prove functionality. The IoT-bridge is not permanently attached to the acrylic pipe so different tags can be detected. The trailer is emulated by a device similar to the IoT-device but without NFC-functionality. It is equipped with an LCD-screen to provide information concerning the detected tag. Every building block has been experimentally validated in the field.

IV. Conclusion

This paper has presented a solution to ensure full traceability of food and feed from the moment it leaves the production site until the moment it enters a silo. Our solution focuses on the link between bulk trailer and silo. We have discussed state of the art concerning communication and identification. A short and long range communication tandem based on NFC and LoRa was conceived. A prototype setup was built, validated and showcases functionality.

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