LoRaWAN for IoT Applications in Air Cargo
Development of a GSE Tracking System for DHL Air Cargo Hub Leipzig

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Abstract — Air cargo handling is particularly time-sensitive. Handling processes have to be planned and managed with corresponding efficiency. The paper describes the development and current testing of a tracking system that keeps track of which equipment is located where on the airport apron under what condition. LoRaWAN connectivity is used to transmit equipment locations and loading conditions in the sense of the Internet of Things. This helps apron management plan and control apron processes more efficiently. This paper describes the development of the system solution and the development methodology.

Keywords — Internet of Things, LoRa,
LoRaWAN, GNSS, tracking, condition detection, air cargo, smart logistics zone

I. INTRODUCTION

Over 2,000 tons of cargo are handled at DHL’s largest air cargo hub in Europe at Leipzig/Halle Airport (LEJ) every night. Cargo is delivered and shipped in so-called unit load devices (ULD) – air cargo containers and pallets – chiefly by airplane. Cargo is handled at the warehouse where arriving ULDs are unloaded, systems sort cargo by recipient’s address, and empty ULDs are subsequently reloaded for forwarding.

Fig. 1: Dolly with roller deck (Photo: Stefan Marx / DHL Hub Leipzig GmbH)

So-called dollies transport ULDs on the apron between individual aircraft stands and the warehouse. These simple dollies with a roller deck (Fig. 1) can be used flexibly for the more than ten different sizes of ULDs. Having no engine or energy storage system of their own, dollies are transported at the air cargo hub by tow tractors – also called tug – in a tow train (Fig. 2).

Fig. 2: Tow tractor with four dollies loaded with ULDs (Photo: Dirk Mahler / Fraunhofer IFF)

Air cargo handling at the hub is time-sensitive since the individual shipments from different origins have to reach their respective connecting flights. Enough empty dollies always have to be available to handle orders to ensure cargo is handled efficiently. Substantial labor and material is expended to prepare nightly cargo handling to do so at present. This includes labor for searches and planning as well as rental of additional dollies from the airport when bottlenecks occur.

Information on the number of (empty) dollies ready for use and their exact location on the apron is currently unavailable during regular operation. Substantial time and expense goes into capturing the number of dollies available, their loading condition and their particular stand every day. This serves as the basis for allocating a suitable number of dollies for nighttime operation based on the anticipated ULDs handled.

Tug drivers have to search anew for empty dollies during routine nighttime operation to complete their handling jobs. They drive around the premises covering a maximum of 200 hectares at their own discretion and collect empty dollies. Such searches require a good deal of time and consume fuel unnecessarily.

Given this starting situation, DHL’s hub intends to use a dolly tracking system to track current location and loading condition, thus eliminating daytime counting and nighttime searches. Dollies thus become data providers in the sense of the Internet of Things. IoT modules moving on the airport apron will facilitate the implementation of major developments for a smart airport logistics zone [1].
Together with industry partners, the Fraunhofer IFF developed as system that tracks ground support equipment (GSE) such as dolly. It is currently being tested at DHL’s hub in an extensive test application. Along with the tracking and load detection requirements, wireless energy-saving transmission of status data also plays a major role in the application. This paper describes the development methodology and testing of the system solution outlined in Fig. 3.

First, the specifications for the GSE tracker are analyzed (Section II). Then, the preliminary technical considerations of LoRaWAN use for data transmission as well as the evaluation of available LoRa connectivity at LEJ Airport are presented (Sections III and IV). The engineering of the tracking modules is described in Section V. The paper closes with conclusion and outlook (Section VI).

II. REQUIREMENTS OF GSE TRACKING

The parameters and specifications of a GSE tracking system were analyzed together with DHL Hub Leipzig GmbH in a requirements analysis. A distinction is made between:

- the ambient conditions of system use,
- the requirements on data obtained with the system,
- the requirements on operation of a system solution, and
- the availability of relevant technical solutions.

Since dollies are used outdoors throughout the year, GSE tracking hardware has to withstand temperature fluctuations between -20 °C and +50 °C and stresses from rain, snow, hail and deicing fluid without malfunctioning. High mechanical robustness is also essential since ULDs sometimes weighing several tons are transported with and moved over the roller deck. Moreover, dollies with airless tires subject GSE trackers to severe shocks. Since neither GSEs nor dollies have their own power supply, the GSE tracker must be designed to save energy and to have a battery of its own. What is more, the capital expenditures and cost of installation in the infrastructure should be minimal. This precludes installations of complex receiver infrastructures.

Efficient management of the over 1,500 dollies at DHL’s hub requires knowledge of each dolly’s current location data and loading condition. Dollies will be located by an integrated tracking system. GPS/Glonass will be employed for outdoor tracking, the main use. Cellular tracking options should also be available indoors e.g. workshop. Since the GNSS module will be activated only as needed, the most important criterion for the GNSS module is its time to first fix (TTFF) in conjunction with its power consumption.

The sensor that detects loading condition is one of the most important components. This sensor must be able to scan the sheet aluminum floor of every potential type of ULD (containers and pallets). The challenge here is the need to mask the dollies’ sheet steel top on which the sensor is mounted. The sensor must be installed to be immune to rain, icing and complete coverage by snow and nevertheless detect the ULD’s floor reliably. Since ULD floors are generally not level, zero to three centimeters was defined as the detection range. The sensor’s power consumption must be minimal to save the limited battery capacity of the GSE tracking device.

Along with detection of loading condition, one of the fundamental demands is the transmission of computed doly data to a central location over several kilometers while consuming little energy.

Rechargeable batteries will supply the tracking system on the dollies so that they can be equipped rapidly. Batteries should have a life of at least one year, thus making it possible to replace them without any problem when dollies are routinely serviced in the workshop.

To match the requirements towards low energy consumption of the tracking modules and wide area communication LPWAN (Low Power Wide Area Network) technologies were selected to collect and transmit data. LPWAN technologies are suitable for the use case due to the a high range of a single gateway, low energy consumption of the modules and low bandwidth [2], which is sufficient for the examined use case. With their characteristics, LPWAN technologies have the capacity to open new logistics applications for the Internet of Things, which were previously unfeasible because of high energy consumption and high costs of standard mobile communication [3].

LoRaWAN (Long Range Wide Area Network), specified in recent years, was used as the LPWAN technology to define a protocol that enables transmitting bidirectional data over great distances (several kilometers) while consuming very little energy [4, 5]. Development of LoRaWAN technology created the basis for satisfying the basic requirements of GSE tracking with low energy consumption and a large data transmission range. LoRaWAN was chosen as LPWAN due to its availability.

Fig. 3: GSE tracking system solution development methodology