Smart Services Through Smart Item Agent

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***Abstract*—This work deals with the realization of smart item agent, which is equipped with motion, vibration, acceleration, temperature, humidity sensors and a tracking module through GPS (Global Position System). The main reason for choosing this solution was to reduce crash delivery problems and increase the quality of services. These two problems are very interesting for postal or logistics providers. Item agent collects data during transport in the logistics process of the selected organization. The output is a summary of the data used to monitor the quality and identification of the different services that are provided to the selected type of items. The configuration is an intelligent agent addressed as follows: The heart of the agent is a programmable integrated circuit, which takes care of collecting and storing information from the sensors mentioned above. Part of the agent may also be a GSM (Global System for Mobile Communications) module, which allows us to track the shipment in real time, but at the cost of lower battery life cycle agent. The collected data will be used to improve the organization of its services and the ability to identify the failure of the service at a specific point in the logistics chain through smart sensor package. The results of our research are represented by the solution (smart agent) and also the methodology for diagnosing the quality of services in conjunction with postal or logistics operator needs.**

Keywords-postal sector; postal package; MCU; smart sensors; IoT.

I. INTRODUCTION

Quality in the field of postal services could be defined as a file of used properties of service taking into account the fact that the service would be performed according to standards and requests of customers. That is one reason why postal operators perform quality monitoring of their services [1][2].

Quality monitoring in postal services in terms of letter mails is indeed nothing special for most of postal operators nowadays. The entire process of quality monitoring deals with move tracking of selected tested postal mails at the same time in recording of their respective time stamps at the time of passing through particular transfer points. This process can be performed either by the use of barcodes technology, or more frequently, by the use of RFID technology (Radio-Frequency Identification). However, this process is performed at a large scale for postal letter mails only due to adherence of various national as well as international standards. Thus, these measurements give only information including the time and place of passage of postal correspondence. This information is sufficient for the service "delivery of correspondence" [3][4].

Besides postal letter mails that have continuous gradual decrease of volumes, there is also another group of postal products that, unlike letter mails, have managed to achieve growing tendencies – postal parcels. With its nature, this service in question allows to transport various commodities and goods of various sizes, etc. The question is what kind of other quality parameter could be considered for this service, except for those already assessed for postal letter mails. The subject of postal letter mails service is a delivery of content (mostly papers) to addressee of respective postal mail. Once the content of a letter is readable, a quality fact can be taken into account. In case of postal parcels service, it is a little bit different. The subject of postal parcels service is transport of respective product, meaning also non-paper form. If a content of a mail is article with respective function, grade and quality, let us assume that these properties should not distinguish between dispatching and delivery to final addressee. Based on a real-life experience, it is not always the case. Extensive analysis revealed potential causes of damage or loss of postal parcels [5][6]. There are several reasons for potential damage of postal parcels:

a. Inadequate packed mail (improper cover, filling, in the case of multipart goods to their poor attachment),
b. Inadequate placing of mail into transport or manipulation unit (in a real case, this means bad storing of postal parcels in postal crates, truck or even into a mailing rate),
c. Inadequate manipulation of mail (loading and unloading of the mailing, moving postal parcel through sorting system),
d. Inadequate selection of transport route (poor choice of transport communication in poor condition etc.),
e. and more [7][8].

These activities could eventually impose impairment of content, reduction of mail, reduction of functionality, grade or quality of content. The detection of the exact point of any inaccuracy occurrence is very complex, as these are detected just after their final delivery to addressee. Even though we

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could detect, in which phase of transport process the inadequacy in question had been made, it is not obvious which activities had preceded to it. As it has already been said, the postal service package is used for transporting various goods. From this, we can conclude that each specific item should be packaged specifically for the transport path and specifically transported. For example, glass must be transported so as not to be broken or foods, flowers, etc. should be transported in such a package, to prevent overheating and super cooling due to the weather and similar cases. It would be advantageous to have a tool that could record negative influence on the content of transported parcels. That is why this research was started, which subsequently was referred to as Smart agent.

Therefore, a question could be raised if it is suitable to perform quality monitoring also for postal parcels, allowing by its own nature a capture of more relevant data than just points and time of pass-over of postal mail through postal transport network [9][10].

In the second section, we briefly discuss about the current state of usage of smart sensors in the postal sector and we have provided a reason for the realization of the solution. In the third section, we specify the requirements and present the logical design of smart agent. The fourth section is devoted to describing the parcel shipping process for the selected postal operator. An inseparable part of this section is a design methodology for measuring of this operator. In the fifth section, we describe the measurement process itself through smart agent. The sixth section is devoted to the interpretation of the measurement results. In the final section, we highlight the value of the whole issue and suggest other possible steps.

II. Analysis of current situtation

There is currently a large number of technical solutions that enable logging and also forward data captured via smart sensors. These solutions are then useful in many areas of human life [11].

In our paper, we are primarily interested in the area of the postal sector. These solutions are of course applicable where it is relevant or necessary to collect this data. There is a small number of postal operators using smart sensors in their activities. A large group of the above-mentioned postal operators uses smart sensors for mapping or monitoring of their processes. A further group of postal operators uses smart sensors as an additional service for their transportation services. These are mainly packages or even transport units. The reason for developing our own solution lies in poorly scalable and modifiable commercial solution for our particular area of interest. Another reason was the involvement of students in problem solving of selected postal operator with whom we have cooperated in the development of the device.

III. Concept of smart agent

The current development of information-communication technologies allows to apply an electronics of minimal dimensions even into the field where we could hardly imagine to be applied in past. As a proof, let us use the application of RFID technology into almost all the fields of human activity. We can say that the whole concept of its essence is increasingly approaching the issue of Internet of Things (IoT), or a subset of it called internet processes (IoPro – Internet of Processes). In essence, this philosophy deals with the interaction of the reporting entity with different influences captured through intelligent sensors. So, not only it allows tracking the subject and the influences acting on it, but it does to some extent capture and portray the processes associated with it.

The result of our attempts has been a realization of a small electronic equipment that would be put into the postal parcel, whereby the measurement would be performed likewise at postal letter mails by use of testing parcel. Indeed, fields of application can be eventually much wider, either for postal operator or final user of respective postal service. Despite the great potential of this device, it is planned to be used only on repeated testing of specific parts of postal transportation network of postal operators. This situation affects the price for the components of the device. The purchase price ranges from 16 to 35 Euros, using components with online and offline versions.

The foundation of our equipment is energy-efficient integrated circuits, which are connected with intelligent sensors. Connected storage media were used for data storage and battery power with sufficient capacity were considered [12].

The basic components of the smart agent:

- The energy control unit MCU (microcontroller or Micro Control Unit),
- Intelligent sensors (humidity, gyroscope, acceleration, temperature)
- External storage memory,
- Battery power.

Additional components:

- GSM module (Global System for Mobile Communications),
- GPS module (Global Positioning System),
- Intelligent sensors (falls, stresses).

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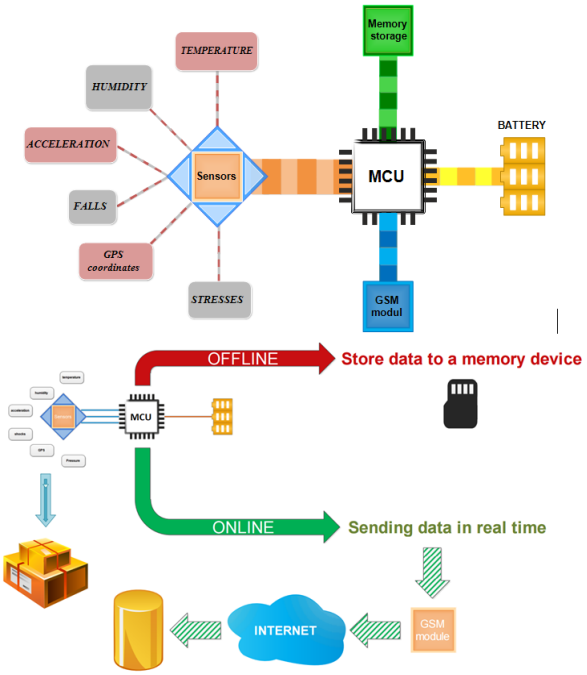

Figure 1. Concept of Smart agent.

Figure 1 represents two proposals for a smart agent. The difference is access to recorded information. The online version of the smart agent is accessing data in real time. The off-line version of the smart agent has access to the data after completion of the transport process.

IV. MEASUREMENT METODOLOGY

The main impetus for the implementation of smart tools agent was needed to identify the factors that may affect the postal parcel dispatch time after transport. After the implementation of a smart agent and related laboratory performance tests, realistic tests were performed. Our measurements were carried out at an unnamed postal operator. For the purposes of this article, we will refer to it as a general postal operator.

Now, we proceed to the preparation process and implementation of measurement. As already mentioned, the subject of our measurement was to capture the negative influences that can affect the content of postal parcels. We chose a trio of sensors. For this measurement, we activated the following sensors:

- Temperature (° C - Celsius),
- Humidity (% RH - Relative Humidity),
- Accelerometer and gyroscope ($m.s^{-2}$).

Through these sensors, we were able to determine the degree of humidity, temperature, acceleration in each vectors direction of postal parcel and of course location of the package through the gyroscope. Beside general acceleration, we also considered acceleration toward Earth´s surface. All these data were recorded on a storage medium (external memory) connected to the smart agent. Other data that were used for efficient analysis data were obtained from the postal operator. We used information on the arrival and departure times of the postal rate for loading and unloading, and of course, the approximate time of manual and mechanized handling parcels. Basic statistical methods [13] were used for processing and analysis of these values.

A. The principle of treatment of postal parcels

Phase 1. Within first phase, we obtained the pre-sorted parcels coming from processing node. In next step, the parcels were sorted at central processing center. Consequently, these consignments were transported at the appropriate time to a central processing center, where the scope of the processing node belongs. **Phase 2.** Here, the shipments are automatically processed and routed through sorting lines (see Figure 2). According to the site directed (resp. Sites) shipments, either transferred to other central processing centers (see Figure 2) or subsequently through non-mechanized (pedestrian) or mechanized centers delivered to the addressee (see the **Phase 3** Figure 2). The same procedure is repeated in other central processing centers.

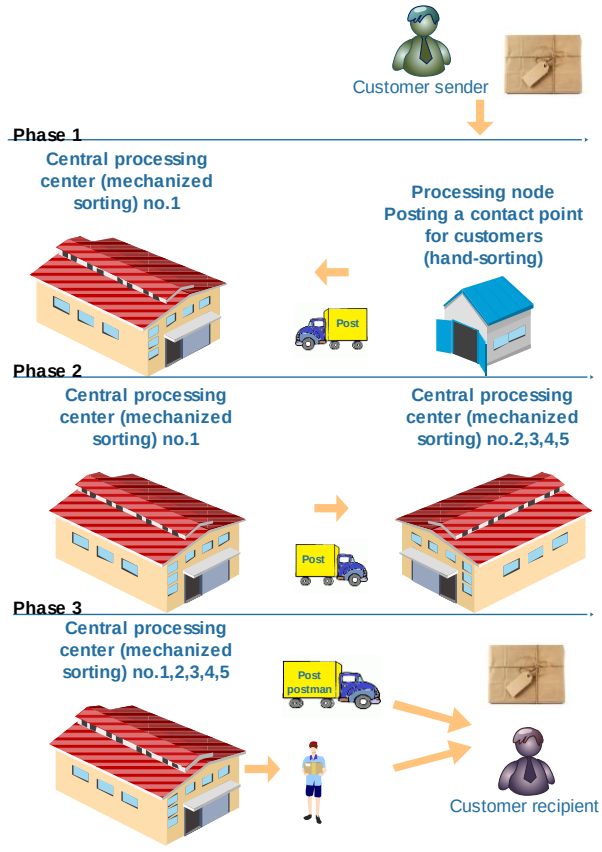

Figure 2. Principle of treatment of postal parcels.

B. Preparation of measurement

For our testing, we used standard cardboard packaging sizes 350x250x120mm. The weight of this packaging was 184 g. Our smart agent weighted 258 grams including

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batteries. Together, the smart agent with the envelope and the inner lining weighted 556 grams.

V. MEASUREMENT

In our measurements, we tested the consignment coming from the postal transportation network of postal operator. In our measurements we used just part of postal transport network described in Figure 2. This particular consignment is characterized in the context of Figure 2, the first phase. So, we filed a smart agent in the aforementioned packaging to transport node. From there, the shipment was transported to a central processing center and went through the whole process of sort order. Based on the agreement with the workers of sorting facility, the package was removed with a smart agent at the end of the sorting process and the following day handed over to our team. The entire schedule is more evident in Figure 3.

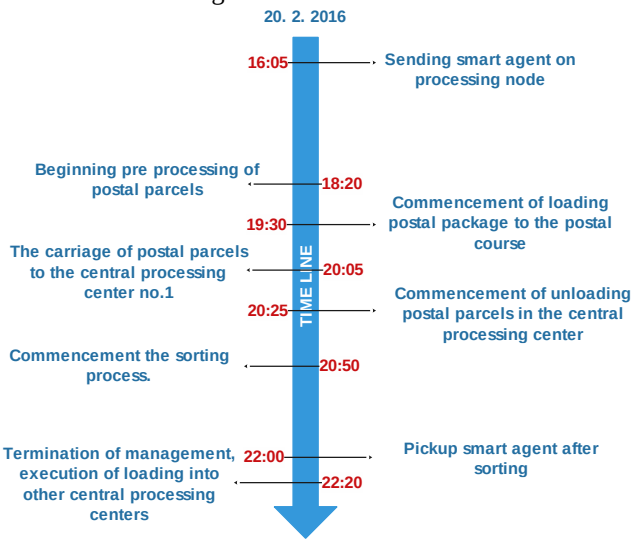

Figure 3. Time line of measurement.

The entire schedule is more evident in Figure 3. There was only one group of data which had a higher value. And this value is 7.345 ms2 and the directional vector 'Z' at position 1, see in Figure 4.

VI. MEASUREMENT RESULT

Through this measurement, we were able to obtain 339,303 groups of values. Each group contained five values. Now, we can move on to concrete results.

A. Position of the postal parcel

The whole measurement took less than six hours. During this period the consignment of several position changes. From the data analysis it is quite difficult to ascertain the exact number of these changes, because in many cases postal parcel remained on one edge. If we exclude these values, the number of position changes would equal 14th. The following Table 1 and Figure 4 represent the time duration in the different positions within the measurement.

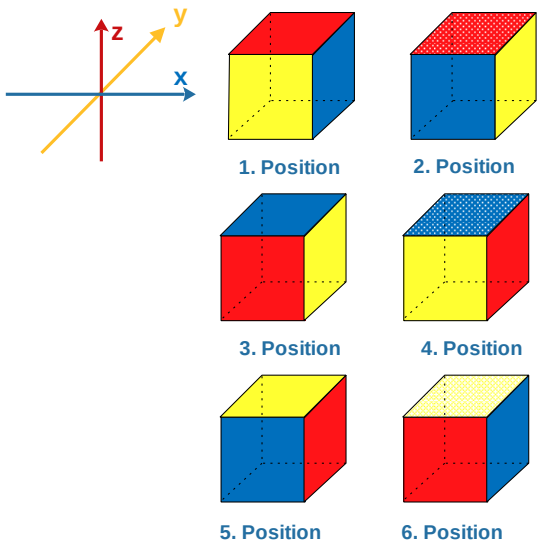

Figure 4. Position of postal parcel.

TABLE I. %TIME SPENT IN EACH POSITION

Position 1	Position 2	Position 3
71,12%	*0,62%*	*3,62%*
Position 4	**Position 5**	**Position 6**
12,24%	*3,67%*	*8,74%*

We find it very difficult to establish clear position of mailings. The reason for this is again the case that a considerable number of values are already on the edge; see Table I that represent % time which smart agent spent in each position. As expected, the largest shipment time was spent in position 1. The reason is simple, because at this postal operator, there is a regulation that says that all the postal parcel must be addressed side up. This regulation is intended to eliminate the time required for changing the position of postal parcel before entering the sorting device. This fact is important for the correct load the address side of the postal parcel by barcode reader on the sorting line. In general, this regulation sets specific parameters for postal parcels. In this regulation postal parcel need to be set with the address side facing up.

As we can see in Table I, over 28% of time spent by the smart agent was in other position at the transport process. In the largest extent, this consignment was incorrectly positioned on processing node.

B. Acceleration of postal parcel

In the laboratory testing we received information from smart agent based on acceleration. We used the same smart agent parcel for real and also laboratory conditions. From

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the large amounts of data, it was found that most of the data acceleration ranges from range from (0,22; 5,936) $m.s^{-2}$ in all three directional vectors.

There was only one group of data which had a higher value. And this value is 7.345 $m.s^{-2}$ and the directional vector 'Z' at position 1; see Figure 4. In terms of time data provided to us by postal operator, it could be just about downhill shipments sorting line. In the phase postal parcels moved from sorting line to belt conveyor and fell down through the slip. This value corresponds to the base data during laboratory testing. This value corresponds to a fall from a height to 80 cm, which can be described as acceptable value. That postal operator gives one specific information regarding the nature of the postal parcel and said, "Cover postal parcel must be modified so that the content of postal parcels withstands a fall from a height of 120 cm".

C. Temperature and humidity

The sudden change in temperature or excessive humidity can to some extent negatively affect the contents of the consignment. It was the reason why we used these two sensors (temperature and accelerometer sensor). On the temperature, we were interested primarily in a sudden change in temperature. We have assumed a large change in temperature between output and input into organizational units of transport. Unfortunately, this effect appeared. There were several reasons. The first of them was the precision packing of our postal parcel and the other too little variance in temperature. Summary of temperatures is given in Table II.

TABLE II. SUMMARY OF TEMPERATURE

Temp-min	Temp-max	Temp-avg
6,50	*11,00*	*8,37*

TABLE III. SUMMARY OF HUMIDITY

HR-min	HR-max	HR-avg
48%	*74%*	*66%*

Unfortunately, the same problem also affected moisture data. Each measurement depends on the forecast condition. Summary of humidity is given in Table III.

VII. CONCLUSION AND FUTURE WORK

The current results of the smart agent are foundations for its own improvement. Through this measurement, we gained a large amount of data; but, without precise identification of the specific area where data originated. In the results, we relied on data obtained from the postal operator, which ultimately appeared to be too inaccurate. Therefore, we want to equip our smart agent with additional sensors that will help us to eliminate the negative aspects of data processing. One of them is the GPS module and the second is an electronic compass. We currently have in development an on-line version of the smart agent, i.e., a version that will allow batch sending this data via services of mobile networks.

Despite all the difficulties, we believe that the concept of smart agent represents a further step not only to eliminate bottlenecks shipping process but also to connect IoT with reality.

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