Application of Internet of Things in food packaging and transportation

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Abstract: Food safety is a scientific field which includes a number of routines and inspections at every stage of the food chain that should be adopted to avoid potentially dangerous health risks. Novel and efficient solutions across the supply chain are the consequence of constant upgrades of information and communication technologies. With the help of internet of things (IoT) connected testing equipment, food quality can be monitored at any point from farm to table, connecting at the same time food producers, transportation and hospitality/retail companies. Relying on the fact that food transporting and packaging units are the most critical points in food production, the survey of IoT applications in food packaging and transportation is given in this paper. To demonstrate the significance of IoT appliance and defined concepts, a proposal of low cost solution based on IoT for real-time food traceability and monitoring in food transportation process is presented.

Keywords: food packaging; monitoring; transportation; traceability; internet of things; IoT; Raspberry Pi; RPi.

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1 Introduction

Looking at history of food, the world we know today has progressed through hunter-gatherer, agricultural, and industrial stages to become a supplier of goods and services. It is somehow astonishing how far the food manufactures and supply chains have come throughout the years. The discipline devoted to the subject of food is food science and it consists of analytical chemistry, biotechnology, engineering, nutrition, quality control, and food safety management. The food safety system includes food production, processing, packing, distribution/transportation, storage and preparation. Every stage of the food chain should be carried out and monitored scrupulously to enhance food safety. Therefore, Food Safety Management System (FSMS) can be defined as a network of interrelated elements (programs, plans, policies, procedures, practices, processes, goals, objectives, methods, controls, roles, responsibilities, relationships, documents, records, and resources) that combine to avoid potentially dangerous health hazards (Figure 1).

Figure 1 Food Safety Management System (see online version for colours)

Considering that safe food is an essential part in the preventing foodborne illness, and that in the last decade, we are confronted with a dozen food crisis, the public concern about food quality has been intensified in recent years. Food contaminants can get into the food supply at any point from farm to table and key global food safety concerns include: spread of microbiological hazards; chemical food contaminants; assessments of new food technologies (such as genetically modified food); and strong food safety systems (to ensure a safe global food chain). To ensure that food reaches its destination in a safe condition without compromising quality, it is necessary to provide an environment that reduces the risk of contamination and protects food from various hazards. Also, there is a need to develop comprehensive and well-designed food contaminants monitoring systems. Bar codes (QR codes or similar matrix barcodes), Universal Product Codes, and radio frequency identification (RFID) labels are common to allow automated information management in logistics and retailing at global scale. Packaging may have visible registration marks and other printing calibration/troubleshooting cues. Food science appliance to the selection, preservation, processing, packaging, distribution, and use of safe food is known as food technology. In other words, food science and technology have evolved to make food the basis of a healthy civilisation, help society overcome hunger and disease, and improve safety, nutrition, convenience, affordability and availability of foods (Hayden, 2010).

Literature reviews have shown that the most critical points for the entrance of contaminants in the chain from farm to the table are food packaging and food transportation.

Food packaging is the technology of enclosing or protecting food products for distribution, storage, sale, and use. In other words, it is an industry technique that may be used along with food preservation and has the intent of slowing down or stopping spoilage that would otherwise exhibit loss of taste, textural quality, or nutritive value of food (Vaclavik and Christian, 2014). Food packaging evolved with the progress of knowledge from crude materials used in ancient times (wooden boxes, ceramic amphorae, pottery vases, etc.) to advanced packaging materials and processes used nowadays.

The safe transportation of food is a key step to ensure the food, that ultimately reaches the consumer, is safe to eat and of the highest quality, as improper and unhygienic transportation could lead to breaking the food safety circle. Many studies have indicated that improper food transportation could lead to food poisoning or food spoilage (Miller, 2013).

According to European Union (EU) law, the ability to track any food, feed, food-producing animal or substance that will be used for consumption, through all phases of production, processing and distribution is called 'traceability' (European Communities, 2007). Food traceability system did not remain immune to continuous upgrading in Information and Communications Technology (ICT) sector. A technology like mobile phones, RFID systems, wireless sensor networks, global positioning systems – GPS (Karippacheril et al., 2011), and internet of things (IoT), as an important part of the new generation information technology, are nowadays applied in food chain in order to ensure efficient delivery and food safety according to adequate standards. IoT is an emerging paradigm and a cutting edge technology which goal is to enable things/objects to be connected anytime, anyplace, with anything and anyone ideally using any route/network. IoT and digital printing technologies (from smart tags, printed electronics and embedded chips to cloud computing infrastructure and high-speed variable data printers), along with the mass adoption of mobile devices and ubiquitous broadband connectivity has created an opportunity to 'make products smart' by connecting them to the web via their packaging (Hobsbawm, 2014). Therefore, IoT nowadays ensures efficient delivery and food safety, which are compliant with food safety and traceability standards and hence makes possible a new cooperative between food producers, transportation and hospitality/retail companies. With the help of IoT-connected testing equipment, it is possible to track and trace packages connected to a network, and thus the food quality can be monitored as food leaves the factory or warehouse. In this way food companies across the supply chain gain the real-time visibility and enable the automated, intelligent actions needed to ensure high food quality, delivery on time and food preparation in optimal conditions (Jones, 2014).

Based on the above mentioned, it is clear that changes in consumer preference for safe food have led to new demands in food packaging and transportation technologies. IoT could be one of the new technological tools which could successfully satisfy to all high demands for safe food consumption. The constant progress of food safety, defined as a public health priority, dictates the necessity to perform an analysis of existing standards, techniques and methods which present the well-known principles at the global level. Therefore, the goals of this paper are:

- the survey of global standards and requirements as well as novel techniques in food packaging and transportation
- the appliance of novel techniques in real food safety monitoring system.

Thus, the rest of this paper is organised as follows. The food safety regulation and standards are presented in Section 2. Section 3 presents novel techniques' appliance in food packaging and transportation processes. Appliance of novel techniques in real food safety monitoring system as well as proposition of low cost IoT solution is given in Section 4. Finally, Section 5, based on the performed research, provides conclusion remarks and outlines directions for future work.

2 Standards and regulations

EU as a response to food contamination applies a set of laws and standards for food traceability through all stages of production, processing and distribution, forcing that all food and feed operators implement special traceability systems. In order to achieve overall efficiency and effectiveness in the food chain and to develop an integrated food control, it is necessary to rely on established standards for food safety: Hazard Analysis and Critical Control Points (HACCP), ISO 22000:22005, International Featured Standard (IFS), British Retail Consortium (BRC) and Safe Quality Food (SQF), which are based on the principle of traceability – the possibilities to track any food, feed, food-producing animal or substance that will be used for consumption, through all stages of production, processing and distribution (Kulina Consulting, 2010):

- HACCP is a scientific and systematic preventive approach to food safety from biological, chemical and physical hazards in production processes that can cause the finished product to be unsafe, and designs measurements to scale down these risks to a safe point. HACCP is used in all stages of a food production. In this manner, HACCP is referred as the prevention of hazards rather than relying on end-product testing (Center for Food Safety, 2007; The Amber Valley, 2014). The seven principles of a HACCP system are (Center for Food Safety, 2007): identifying any biological, chemical, or physical hazards, identifying the critical control points, establishing critical limits, monitoring critical control points, establishing corrective actions, verification and record keeping.
- ISO 22000:2005 sets out the requirements for a food safety management system and can be certified to. It defines what an organisation needs to do to prove its ability to control food safety hazards in order to ensure that food is safe. It can be applied by any organisation irrespective of its size or position in the food chain.
- IFS Food is a standard for certifying the safety and quality of food products and production processes. IFS Food contains ten so called 'knock-out' criteria and applies only to companies processing and packaging (unpacked) food products. In other words, it shall not apply to the: import, trade, transport, warehousing and distribution.
- BRC standards guarantee the standardisation of quality, safety and operational criteria and ensure that manufacturers meet their legal responsibilities and provide protection for the consumer.
- The SQF standard is unique and provides certification for every stage of the supply chain, from primary production and manufacturing, to distribution, packaging and wholesale.

In addition to above mentioned food safety standards, it is important to point out that to ensure traceability system (production, inspection, supervision and consumption), it is necessary to implement a set of GS1 standards which is de facto default way for communication of customers, suppliers and partners. GS1 provides a concept and technology for efficient way of accessing information about items in their supply chains, and share this information with trading partners. All organisations must be a member of GS1, and they obtain a GS1 company prefix which forms the basis of ID keys, unique identifiers for products, documents, physical locations and more. A technology which GS1 provides for identification of products is 1D and 2D barcodes, and lately commonly used a RFID tag. RFID technology, as opposed to bar code technology, defines each individual product, not just a product of the same group. This opens the possibility of determining the content of each product, as well as the date of origin, shelf life, storage conditions of the product or the availability of relevant information about inventory, logistics and freshness of food to manufacturers, suppliers and retailers at any time (Centers for Disease Control and Prevention, 2015). Linking the barcode identification system and RFID technology, GS1 defines Electronic Product Code (EPC) as a universal tag that provides a unique identity for every physical object anywhere in the world. It can be said that the GS1 defined traceability as a business process, but also has developed a global standard for traceability, which is based on advanced technologies and relevant GS1 System tools (Tehnološki Fakultet Zvornik, 2012).

All mentioned standards ensure the ability to follow a food related material or product through all stages of the supply and distribution chain as a vital factor for consumer safety (Kozlowski, 2012). The standards for food traceability have been mandated internationally; by law in the EU, Japan, and more recently the USA; and by private firms and associations (Karippacheril et al., 2011).

Preventive controls for food transportation safety hazards are identified by the expert panel and presented in detail by Ackerley et al. (2010). Ryan (2014) by reviewing documents published by the USA, Canada, Australia, Europe, China and Australia, creates a general picture which can serve to guide the standardisation of in-transit food safety systems.

One of the main documents which propose the hygiene rules in total food chain for Europe is Regulation of European Commission EC No 852//2004 On the hygiene of foodstuffs (European Commission Health & Consumers Directorate-General, 2012). It is mainly directed at food businesses and competent authorities, and aims to give guidance on the implementation of the new food hygiene requirements and on related subjects. It covers all food chain, from production to human consumption. The main focus of the Regulation is on the food transportation. The regulation covers primary production. According to the Regulation, "Primary production' means the production, rearing or growing of primary products including harvesting, milking and farmed animal production prior to slaughter. It also includes hunting and fishing and the harvesting of wild products".

European Commission proposes the name Food Contact Materials for materials used in food packaging processes. Different materials can be used as food contact materials. In addition, regulation for each kind of material has been established, too. For example, regulation EU 2015/174 is last edition of regulation for application of plastic materials as food contact material, EU 321/2011, restrict Bisphenol A use in plastic infant feeding bottles, Regulation EU 284/2011 – import procedures for polyamide and melamine plastic kitchenware from China and Hong Kong and many other regulations (European Communities, 2007).

The main set of rules which food contact materials should fulfil in order to be used in food packaging process and good laboratory practice associate with application of materials in contact with food is given in Regulation 1935/2004 and Regulation 2023/2006.

As related to the transport, the Regulation (European Commission Health & Consumers Directorate-General, 2012) emphasise on:

- the transport, storage and handling of primary products at the place of production, provided that this does not substantially alter their nature
- the transport of live animals
- in the case of products of plant origin and fishery products: transport operations to deliver primary products, the nature of which has not been substantially altered, from the place of production to an establishment.

The Regulation covers the main hygiene rules in food chain of milk and milk products, fishery products, eggs and egg packing centres, honey and other products for bee production, and products of plant production.

It is common for all primary products that "conveyances and/or containers used for transporting foodstuffs should be kept clean and maintained in good repair and condition to protect foodstuffs from contamination, where necessary, to be designed and constructed to permit adequate cleaning and/or disinfection. Receptacles in vehicles and/or containers should not to be used for transporting anything other than foodstuffs where this may result in contamination" (European Commission Health & Consumers Directorate-General, 2012).

At the level of primary production, primary products have to be subject of following operations so as to ensure a better presentation, such as:

- packaging without further treatment
- washing of vegetables, removing leaves from vegetables, the sorting of fruit, etc.
- the drying of cereals
- the slaughter, bleeding, gutting, removing fins, refrigeration and wrapping of fish
- centrifugation of honey to remove honeycombs.

Such operations must be considered as normal routine operations at the level of primary production. On the other hand, certain operations carried out on the farm can lead to the contamination of products, e.g., the peeling of potatoes, the slicing of carrots, the bagging of salads with the application of packaging gases or the removal of gases. These operations cannot be considered as normal routine operations at the level of primary production nor as operations associated with primary production.

The Regulation creates the need for food companies to establish, under the HACCP-based procedures, documentation commensurate with the nature and the size of the business. Together, this documentation will constitute operational procedures that are an important element in ensuring food safety.

3 A survey of novel techniques in food packaging and transportation

Food systems stretch from producers to consumers and the responsibility for safe food is shared by all participants in the food system. Therefore, it is crucial to ensure food is packaged and transported in a manner that it is protected from contaminations, transported at adequate temperature to maintain safety and to provide customers with accurate information about the food.

3.1 Food packaging

The food package is used to protect the product from the deteriorative effects of external environmental conditionals like heat, light, presence or absence of moisture, pressure, microorganisms, etc. It provides the consumer with the greater ease of use and time saving convenience and contain product of various size and shapes. The key safety objective for traditional packaging materials which comes in contact with food is to be inert as possible. Technology innovation and the IoT move the packaging market from conventional packaging to interactive, aware, and intelligent (Barnes, 2014). Thus, smart packaging systems like active and intelligent packaging concepts are based on the useful interaction between packaging environment and the food to provide active protection to the food (Biji et al., 2015).

Smart packaging utilises chemical sensor or biosensor to monitor the food quality and safety from the farm to the costumers. This technology can result in a variety of sensor designs that are suitable for monitoring of food quality and safety (freshness, pathogens, leakage, carbon dioxide, oxygen, pH, time or temperature). Thus, this technology is needed as online quality control and safety in term of consumers, authorities and food producers. It has great potential in the development of new sensing systems integrated in the food packaging, which are beyond the existing conventional technologies, like control of weight, volume, colour and appearance (Abdulah et al., 2011).

Packaging materials can be divided in several groups:

1 packaging materials with improved barrier properties

2 active packaging materials

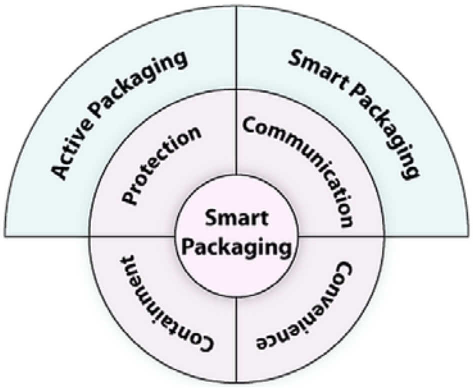
3 intelligent packaging materials

4 edible coatings

5 biodegradable packaging materials.

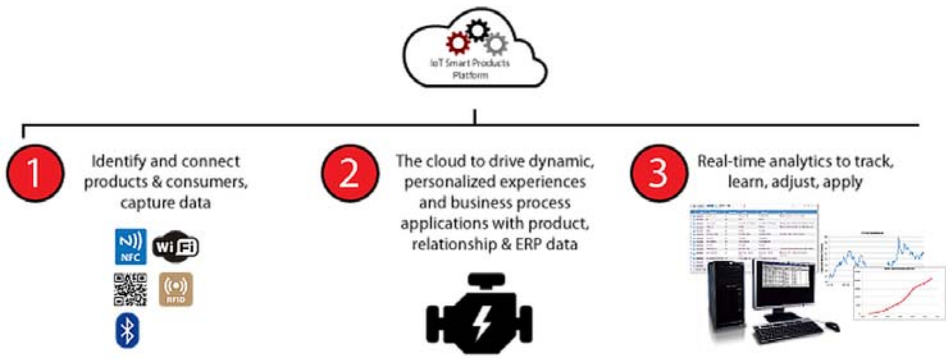
Addition of nanoparticles to the food packaging can improve characteristics such as the barrier properties of packaging to different gases, antimicrobial properties, and biodegradability, to incorporate sensors that can inform of the quality of the food, etc. Currently, the largest category of nanotechnology applications for the food sector is in food packaging materials. However, as nanomaterials have different properties compared to the bulk material, scientific concerns have been raised about the possible hazards to human health and the environment. Thus, other solutions such as IoT are preferred in smart packaging (Rai et al., 2015). In other words, intelligent packaging can leverage IoT and Big Data to establish a dynamic interaction with sensors on packaging such as RFID, Near-Field Communication (NFC), Bluetooth, and smart labels (Wilder, 2015). With the help of these technologies companies can embed sensors to track environmental conditions throughout the supply chain. Yam et al. (2005) define smart packaging concept and principles as it is shown in Figure 2.

Figure 2 Model of packaging functions (see online version for colours)



Smart packaging as a subset of the IoT that combines mobile devices, smart tags and sensors and the cloud is shown in Figure 3.

Figure 3 The principle of work of smart packaging (see online version for colours)



Source: Lingle (2015)

As it is shown in Figure 3 application of smart packaging can improve tracking and tracing of packages connected to a network, thereby helping companies to make educated decisions on-the-fly. Sensors and advanced safe and healthy radiant energy solutions at the point of sale can help extend the product's shelf life while killing harmful bacteria that accelerates the product's decomposition. Every node within the supply chain is recorded and verified from catch-to-consumption. This brings on additional economies of scale, reduces the risk of product recalls, and enables accountability across the industry (Wilder, 2015).

3.2 Food transportation

Ryan (2014) states 15 food main risk problem areas during transportation: refrigeration and temperature control, transportation unit management (prevention, sanitation, etc.), packing, loading and unloading, security, pest control, container design, preventive maintenance, employee hygiene, policies, handling of rejected loads, holding and traceability. Therefore, no matter what kind of food commodities and products are transmitted, they all require common multiple steps in their transportation between point of origin and point of use in order to ensure safe food products transportation and to avoid any contamination (Keener, 2003). Applying new technologies, like IoT, nowadays it is possible to connect food producers, transportation and hospitality/retail companies. RFID technology is generally seen as a key enabler of the IoT, because of its ability to track a large number of uniquely identifiable objects with cost-effective tags. RFID electronic tags store standard and interoperability-utilised information in IoT, which can be automatically gathered into the central information system through a wireless communication network to achieve object identification. In such way the movements of large amounts of products can be tracked in an automated way by inexpensive RFID tags. Accompanied with appropriate software, which uses the information from the transmitted data in order to trigger alerts in response to specific events, RFID and IoT have been shown very useful in product tracking (Aggarwal, 2013). Another possible solution in food tracking is to use conventional wireless sensing technology for building the IoT. An example of such system is introduced in Miller (2013). A wireless food safety monitoring system which sends alarms to PCs, smartphones or tablets if there is a problem with food temperature, door status or humidity speeds up time-consuming and costly HACCP processes and reporting. Also, an automated and portable monitoring system for a HACCP food safety organisation with sophisticated and fast management, responding and supervising feature is presented in Zeidler (2010). Realised low cost wireless remote system with continuous and automated monitoring features and fast response, can be positioned anywhere, collects process and store data, sends alerts and warnings when specifications are not met and creates reports. Wireless networking also enables the creation of sensor networks in vehicular environments, enabling in such way monitoring food safety during transportation. The number of in-vehicle sensors is increasing rapidly and they range from simple to complex systems. The advantage of connected vehicles is in information accessible nearly in real-time and the creation of a sensing network with a massive reach, amplified by the inherent mobility of vehicles. Martins et al. (2012) discuss several applications that rely on vehicular sensing and discuss connectivity issues related to the mobility and limited wireless range of an infrastructure-less network based only on vehicular nodes. Furthermore, in Hsu and Wang (2014) is mentioned a term internet of vehicles (IoV) which is a complex integrated network system that interconnects people within and around vehicles, intelligent systems on board vehicles, and various cyber-physical systems in urban environments. In other words, IoV by integrating vehicles, sensors, and mobile devices into a global network enables various services to be delivered to vehicular and transportation systems, and to people on board and around vehicles. This is performed with the help of contemporary computing techniques such as swarm intelligent computing, crowd sensing and crowd sourcing, social computing, and cloud computing. Ramesh and Das (2012) introduce a MovingNet – a vehicular ad-hoc sensor network, consisted of multiple sensing elements in the public transport system. The advantage of MovingNet is its flexibility to use in different applications only by changing the sensors used in the sensor node or by changing the mobile units, such as vehicles, related to the application. Trying to improve transport efficiency, Zhang et al. (2012) applied the IoT, RFID technology, humidity sensor technology, door switch monitoring device, GPRS/GPS technology and wireless communication technology to create an intelligent remote monitoring system for the refrigerator trucks. Another IoT-based solution is proposed in Xu et al. (2013) in order to monitor the whole process of pork production. They apply the technologies from IoT such as remote monitoring, sensor network, and data mining. The proposed system combines RFID automatic identification technology, sensor technology, ZigBee wireless communication technology, GPS/temperature detection technology and data mining and knowledge discovery technology. Karippacheril et al. (2011) emphasise the significance of mobile devices, advances in communications, and greater affordability of nanotechnology in traceability systems.

Literature reviews have shown that existing approaches in food traceability are summarised into: structured database solutions, RFID-based solutions, barcode technologies, nanosolutions, DNA techniques and nuclear techniques.

4 Appliance of novel techniques in real food safety monitoring system

The likely future impacts of technology on food quality and health in six Central European countries using a key technology survey is investigated in Bakucs et al. (2008). The research challenges connected to food safety can be summarised in Vermesan and Friess (2013):

- design of secure, tamper-proof and cost-efficient mechanisms for tracking food contamination from production to consumers, enabling immediate notification of actors in case of harmful food and communication of trusted information
- secure way of supervising production processes, providing sufficient information and confidence to consumers
- ensure trust and secure exchange of data among applications and infrastructures (farm, packing industry, retailers) to prevent the introduction of false or misleading data, which can affect the health of the citizens or create economic damage to the stakeholders.

Falling costs of hardware and software accompanied with IoT paradigm affects the whole supply chain: starting with the production site, through transport and retail, up to the customer, and therefore can facilitate the whole process and improve the service (Bassi et al., 2013). Recent trends in food safety are focused on miniaturisation of analytical procedures through application of sensors, biosensors, microchips lab-on-a-chip, or micro total analysis systems (Mirasoli et al., 2014). Therefore, nowadays, commercially available hardware and software and solutions' providers offer a variety of approaches for recording, storing and retrieving data. This allows fast detection of possible contamination especially during transportation.

Sensors are a key enabler in the realisation of an IoT and many of the objects associated with the IoT are sensor-based systems. With the help of sensors in food safety system, temperature, humidity, carbon dioxide, heavy metals and other environmental conditions in fields, as well as perishable items during transport can be monitored. With the development of nanotechnology, the use of nanosensors could enable production, processing, and transportation of food products more secure. Packaging equipped with nanosensors that can also act as electronic barcodes, is also designed to track either the internal or external (atmospheric impacts) conditions of food products, pellets and containers, throughout the supply chain (Wesley et al., 2014). These sensors emit a signal that allows food to be tracked from farm to factory to supermarket and beyond. In other words, results of nanosensors detection must be transferred to the mainframe computer for the purpose of processing. Wireless data transfer from food sensors can be done by many protocols, but the cheapest and the most explored way is data transfer via RFID tags. In such way, a large number of nanosensors in combination with active RFID tags can enable determination of any discontinuity in transport or a storage, while utilisation of passive or battery assisted passive (BAP) RFID tags on packages in combination with nanosensors can enable data transfer to the RFID reader and/or mainframe computer (Ileš et al., 2011). Because of their ability to improve safety and prolong the life of food, these nanopackaging solutions are some of the most exciting introductions in the food industry today.

4.1 A proposition of low cost IoT-based solution for monitoring food safety

The main function of food traceability and safety monitoring system is to provide information and record keeping procedures that indicate the path of a product unit, a group of products or ingredients from a supplier, through all intermediate steps along the food chain to the final consumer (Zhang et al., 2011; Ene, 2013). For the fulfilment of the set functionalities, together with rapid technology advancements, a several key requirements which depend on global principles can be defined (Zhang et al., 2011; Ene, 2013):

- wireless, light weight, small size, low cost solution equipped with accurate and stable sensors for an essential variable
- ruggedness and transportability
- non- or minimally-invasive
- compatibility and standardised information
- defining the resources and identification of lots of products
- continuous monitoring functions and real time food safety data gathering at each decision point
- recording information on the production process and establishing links between the information
- sending the result to the cloud automatically so that can be viewed online in a presentation form that is easily understood
- food safety emergency response system: immediate recall and preventive elimination of potential hazards.

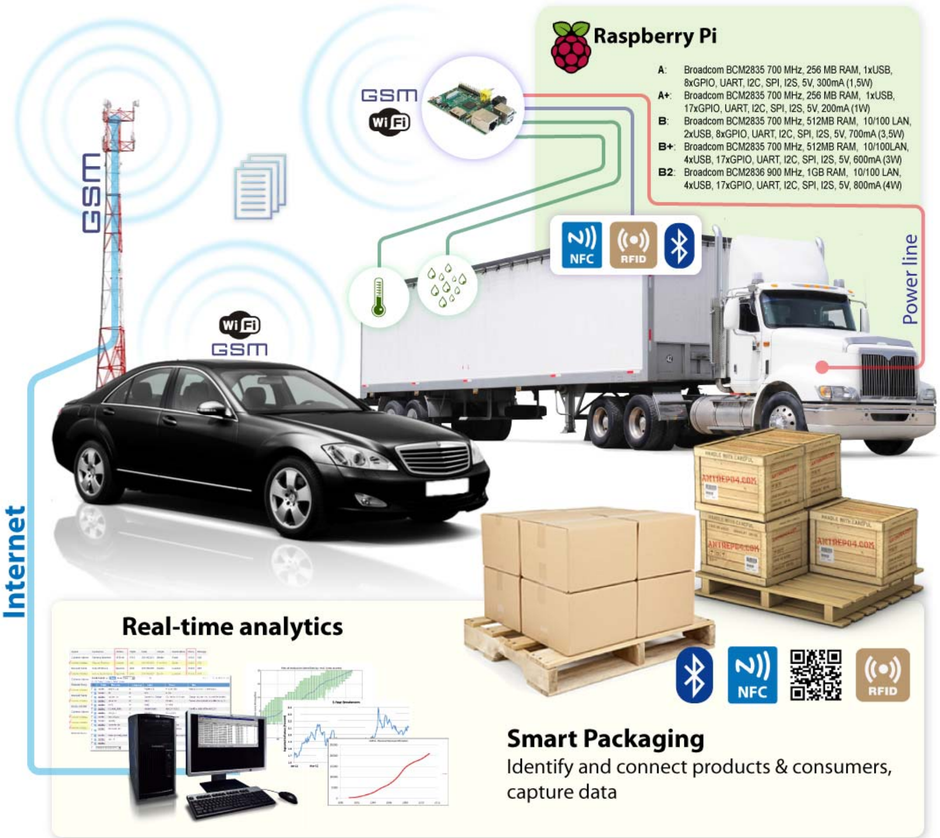
Aforementioned requirements represent a main guideline for building a custom monitoring system which can be applied on global scale issue.

In this paper, the creation of an economical, sensor-based remote monitoring system using cost-saving technology based on cheap computer board and wireless communication modules is proposed. For monitoring, sensor unit represents a main building element which can be combined based on user needs and monitor different elements and parameters of products and its environment. Thus, different parameters as indicators of contamination of foodstuff could be evaluated by such miniaturised device. These parameters could be temperature, humidity, chemical contaminants, microbial contaminants, etc. Increase of temperature and humidity cannot give information about the type of contamination which will happen, but it is a sign of contamination in many types of foodstuff (milk, meat, plants, etc.). Hence, temperature and humidity can be taken as parameters to follow in sensor design in order to have universal sensors for many different foodstuffs. The proposed solution is based on two elements: a traceability (which provides information about a product which is tracked and monitored) and monitoring (which provides a state of the product, package and its environment). Relying on new architecture and technologies in the field of nanotechnology, an extension of the system which will provide support for data collection from smart packaging is also proposed.

Hardware implementation of proposed system is based on low cost computer board Raspberry Pi (RPi) which is used as a central processing unit and offers a lot of services for accessing sensor data, and communicates with end users, while different types of sensors (depending of target parameters) can make the detection module. A RPi is a credit card sized, powerful and lightweight ARM-based computer board which has support for a large number of input and output peripherals, and network communication what makes it the perfect platform for interfacing with many different devices and enables an almost limitless choice of its uses. RPi is running on Linux (version A, A+, B, B+, B2) or Windows 10 (version B2) operating systems, and the whole unit is powered with 5 V and 200–800 mA current, what implies a low-level consumption of 1–4 W (depends on version). Internet connectivity may be via an Ethernet/LAN cable or via a USB WiFi, WiFi Shields, Bluetooth, WiFi/Bluetooth USB Combos, RF Add-ons and cellular solutions (3G/4G USB modem or GSM/GPRS shields). RPi usage as a hardware for building an IoT solution with in detail presented analysis of its performance and constraints is presented in Vujović and Maksimović (2014). A complete solution of RPi utilisation in home automation is presented in Vujović and Maksimović (2015), while proposition of communication over GSM/GPRS is given in Vujović et al. (2015). Akyildiz and Jornet (2010) have introduced the use of nanotechnologies in various domains of applications as well as new technologies and architecture in the field of nanotechnologies like nano-nodes, nano-routers, nano-micro interface devices and gateways which enables the remote control of the nanosensor networks over the internet. Relying on proposed approaches a smart packaging technology can be connected to RPi system and thus provide a detailed information of foodstuff products. Due to lack of technology this part was not implemented; therefore only a conceptual proposal for this solution is given.

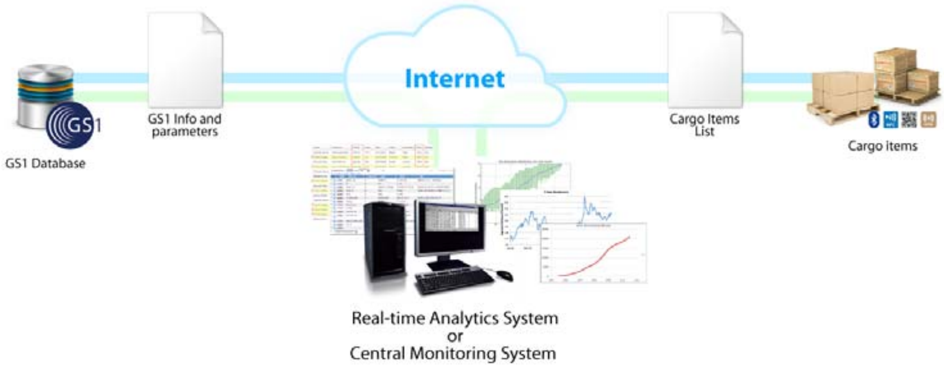
Based on presented knowledge a proposition of custom solution is built and it is shown in Figure 4.

Figure 4 Monitoring food safety during transportation (see online version for colours)



In order to create as much as possible universal solution for monitoring many different foodstuffs during transportation, the cargo area (container, trailer) is equipped with a RPi unit (as a central processing unit) and sensors for measuring temperature and humidity (digital or analogue sensors). The advantage of the proposed system is the fact that additional sensors, depending on special food product monitoring requirements, can be easily added. Beside of that, a whole system is connected to devices for scanning and reading a cargo items (box, pallets, barrels, etc.), usually RFID but also a NFC or Bluetooth devices can be used. As an advanced feature a connection with Smart Packaging can be implemented through nano communication technology described above. In the proposed solution, RESTful web service (RESTful web service) with unique public address and provides worldwide access over the internet (for sending measurement data to the Real-Time analytic System (RTS) or Central Monitoring System (CMS) which is done over Wireless 802.11 or GSM/GPRS module. After the cargo is being loaded on transportation vehicle, a RPi make a scan with middle range RFID and detects all stored items. When items' detection is completed, a cargo list can be read from CMS or accessed through unique Uniform Resource Identifier (URI) address, depending on further analysis. CMS detects and links items to GS1 database, recognising the essential parameters for monitoring (in our case temperature and humidity) during the transportation process, and implements a simple (reading values from sensors and alerting when monitored parameters are disturbed) or complex (a fuzzy logic or neural network-based systems for decision-making) monitoring system (Figure 5).

Figure 5 Detection cargo items and essential parameters for monitoring (see online version for colours)



This solution through monitoring parameters of interest can provide an instant real-time view into food safety and trigger alerts if problems occur so they can be caught before real hazard and damage is done.

The whole system can be powered from a vehicle or autonomous battery power supply. Optionally, the proposed solution can be used in the creation of sensor networks in connected vehicular environments.

5 Conclusions

It is evident that there are so many types of foods with so many containers, temperature and handling requirements as well as so many modes of transportation available to the modern food company. Independently of the mode of transportation, foods and food ingredients are susceptible to abuse and/or contamination during transportation and storage. Foodborne illness is a preventable and the underreported public health problem. Therefore, food safety is a main concern nowadays, and thus it is crucial to have a system which enables foodstuffs traceability and monitoring during the whole food chain process. This paper presented food safety requirements, existing systems, standards and regulations but also it identified novel techniques in food packaging and transportation. It is shown that the traceability information can be accessed through the internet relying on existing standards, and therefore it can be concluded that IoT concepts and technologies enable efficient methods for data gathering, communication and sharing from different resources automatically. IoT, as the third wave of technology that combines mobile devices, smart tags and sensors and the cloud to yield real-time value, provides unprecedented opportunities for product tracking. In such way, a food traceability system can make consumers understand the production and circulation process, and increase consumers' faith to the food itself. In addition, this paper presents appliance of novel techniques and the proposition of low cost solution based on IoT. The advantages of proposed system for foodstuffs monitoring are: low cost, small size, flexibility, rapid system expansion, real time access and automatic cargo identification. Future research will be focused on interconnecting vehicles, sensors, and mobile devices into a global IoV network, what should enable various services to be delivered to vehicular and transportation systems, and to people within and around vehicles.

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