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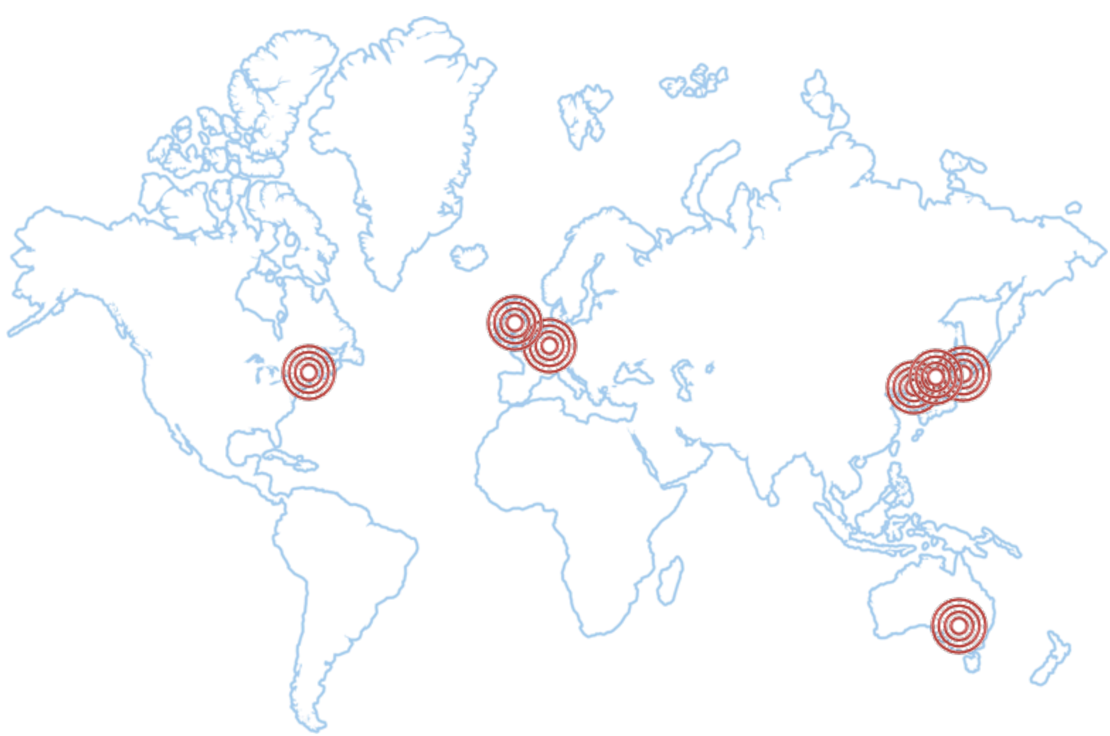
AUTO-ID LABS

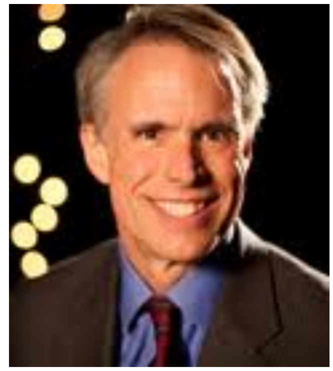
ANNUAL REPORT

Auto-ID Labs Activity 2012 – 2013

July 2013



FOREWORD



Dear Readers,

I'm excited to see this first annual report on the Auto-ID Labs research programs. The primary goal of this new series of reports is to give the GS1 community greater visibility into the key research projects and experts at the Labs, and to increase the value of the Labs and their staffs to the GS1 community as a whole. In particular I would like to highlight the work that the labs are doing in support of our newly-approved GS1 Digital project. The objective of GS1 Digital is to help manufacturers, brand owners, retailers, and consumers engage more effectively across the World Wide Web. This includes helping consumers search for and buy the products that best match their needs, as well as online services and support that help them in their usage of products. The Auto-ID Lab are taking the lead in exploring the best ways of publishing GS1 identification keys and attributes (descriptions, categorizations, transactions, events, etc.) into the code of the Web so that this content is machine readable (e.g., understandable by search engines, and other services). Furthermore there are some closely related work packages 7-10 that look at the opportunities around Digital receipts and digital account management.

I hope you find this report an asset in support of your work, and that you let us know how such reports can be of even greater value to you in the future.

Steve Bratt

Chief Technology Officer and President, Standards, GS1

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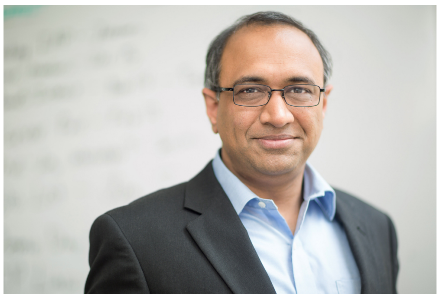
1 INTRODUCTION BY THE LABS



Professor Sanjay Sarma
Auto-ID Lab at MIT

"As the Internet of Things develops and consumers move to the online world, the GS1 community faces several emerging technological and business opportunities as well as threats. This year, the labs are emphasizing the overarching theme of “Future-Proofing” in our research. We identify and summarize these threats and opportunities and recommend future directions for GS1. One recent initiative is GS1 Digital, in which Lab Members are helping GS1 staff formulate a new strategy for GS1 engagement in online commerce. Some of the other highlights include new sensing techniques that present GS1 with the opportunity to develop or extend its repertoire of standards. This work complements the GS1 Digital initiative and opens several opportunities such as pervasive sensor discovery, modeling language development and alert services on the web. We discuss how advancements in smart materials and “antenna-based” sensing unlock applications from agriculture to infrastructure condition monitoring. And we provide insights into how the latest advancements in cloud computing, big data analytics and mobile phone technology facilitates embedded field intelligence - moving us one step closer to the universal inter-connectedness of physical objects." -- *Sanjay Sarma*

Professor Elgar Fleisch
Auto-ID Lab at University of St. Gallen and ETH Zurich

"The merge of the physical with the digital world more and more proves to be an irresistible trend, like a natural force. It not only becomes harder, but also more questionable to distinguish between the offline and the online world. Online concepts suddenly appear in the offline world and lead to new phenomena such as showrooming, and offline technologies start moving into the digital world, e.g. product identifiers are slowly finding their way into the Web. One trigger for this is the smart phone. It enables consumers to look up digital profiles for products anywhere and anytime. And thus it inevitably adds the consumer to the current B2B-oriented business model of GS1. The Auto-ID Labs around the globe take pride in working hard to contribute to the future business model of GS1 with their fact-based and design research driven approach that focuses on imagining, demonstrating, and experimenting with GS1 technologies and applications of the future." -- *Elgar Fleisch*

2 FUTURE PROOFING OF GS1

The Auto-ID Labs emphasize a theme of *Future Proofing GS1* as the central role in its research activities over the next two years. In spring 2012 Professor Sanjay Sarma of MIT, Professor Elgar Fleisch of University of St. Gallen and ETH Zurich, and staff of GS1 determined an initial list of research topics that would be relevant and important to GS1. The resulting cooperation framework was made effective on July 1, 2012 and is continuously reviewed with the GS1 CTO office to ensure a match on the mutually agreed priorities. This report presents an update on the latest research results and insights of the labs. The next sections present the key activities for the cooperation with GS1 and progress reports by individual research topic.

2.1 The Auto-ID Labs at a glance

The Auto-ID Labs are a network of seven academic research labs of world leading universities. The Labs are run by the Auto-ID Labs Board of Directors and currently employ seven directors, nine associate directors, and more than 60 researchers on four continents. The GS1/EPCglobal Board of Governors serves as primary advisor.

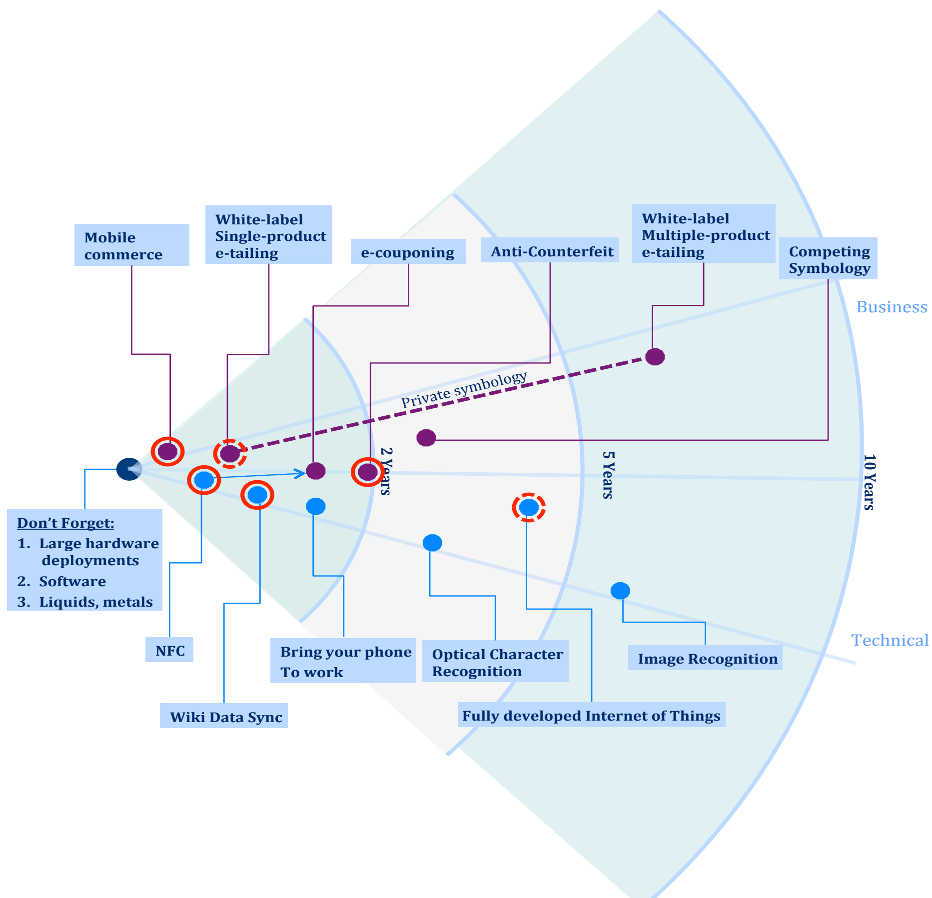
Massachusetts Institute of Technology	**Auto-ID Lab: MIT** **Professor Sanjay Sarma, Director** Rahul Bhattacharyya, Associate Director	USA
University of Cambridge	**Auto-ID Lab: University of Cambridge** **Dr Mark Harrison, Director** Prof. Duncan McFarlane, Research Director	UK
University of St.Gallen ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich	**Auto-ID Lab: University of St. Gallen / ETH Zurich** **Professor Elgar Fleisch, Director** Assistant Prof. Alexander Ilic, Associate Director	Switzerland
	Auto-ID Lab: Fudan University **Professor Hao Min, Director** Associate Prof. Junyu Wang, Associate Director	China
Keio University	**Auto-ID Lab: Keio University** **Professor Jun Murai, Director** Associate Prof. Jin Mitsugi, Associate Director	Japan
KAIST	**Auto-ID Lab: KAIST** **Professor Daeyoung Kim, Director** Assistant Prof. Seong Hoon Kim, Associate Director	Korea
The University of Adelaide Australia	**Auto-ID Lab: University of Adelaide** **Dr. Damith Ranasinghe, Director**	Australia

2.2 Technology watch

The Labs continue to identify and evaluate the upcoming business and technological threats that could marginalize GS1 standards and procedures, thus helping GS1 to "anticipate the future". The results are captured and reviewed in a tool called Tech Watch Radar. The Tech Watch Radar will help to shape GS1's strategy by providing analysis and recommendations from the Auto ID Labs on current and emerging technologies.

2.2.1 Tech Watch Radar

The figure below represents the latest visualization of the Tech Watch Radar and illustrates a threat matrix together with the timelines over which these threats would begin to impact GS1's revenue stream.



The Tech Watch Radar shows the timeline from left to right in which an item might impact GS1 operations. Threats are presented along two dimensions – emerging disruptive technologies and new business paradigms. Each item is represented as a dot with a blue color if it is mainly a technology-driven threat or with a purple dot if it is a business-driven threat. The center line represents an item which is driven by both, business and technology aspects. A red circle around a dot means that there is already a detailed mitigation strategy available whereas a red circle with a dashed line implies that this item is currently under study.

2.2.2 Continuous update and screening process

The Labs and the GS1 CTO are currently evolving the tech watch towards a more open system. This means that any member of a GS1 MO, Auto ID Labs representative or GSMP member will be able to ask questions to drive forum discussion. For all items added, a standardized impact assessment will be conducted to address the following dimensions:

- When will it impact GS1's operations? Measured as time frame of near (2 years), medium (2-5 years), far future (> 5 years)
- Is the item business or technology-driven? Measured as a scale of low, med, high for both dimensions
- Derived actions / implications for research funnel (e.g., policy, strategy, architecture, standards)

The Tech Watch Radar is updated monthly in a joint Auto-ID Labs and GS1 call. The GS1 CTO and a senior team member lead the call from SSD, IE, and operations. The goal is to align on prioritization as well as adding and removing items from the tech watch radar so that only the top 20 items are present.

2.3 Strategic research on key opportunities

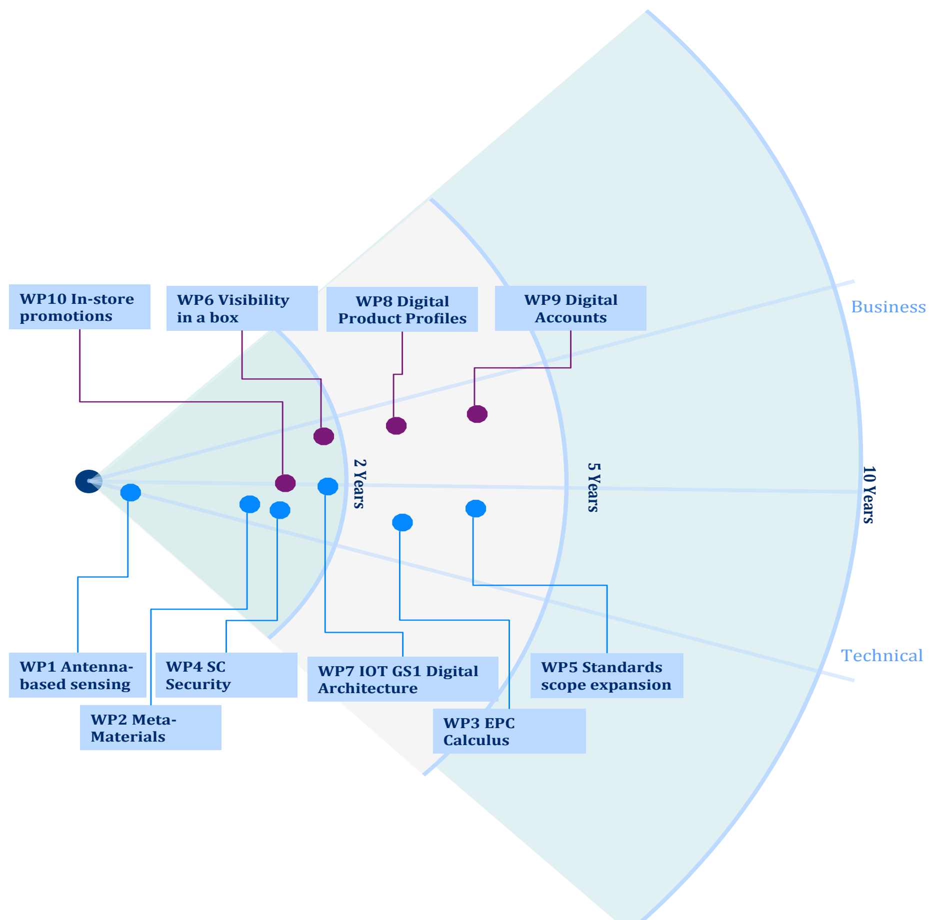
Strategic research is one of the key counter-measures for GS1 to be able to stay ahead and be prepared for the future. The strategic research will help to future proof GS1 by actively shaping the future with new innovations.

2.3.1 Research funnel

The research funnel contains the top ten flagship research projects for shaping the future of GS1 with an emphasis on medium to long-term objectives aligned with the GS1 CTO.

Similar to the methodology of the Tech Watch Radar, each project is categorized with respect to the expected impact on GS1's operations:

- Time horizon of expected impact on GS1 business: short-term, mid-term, long-term
- Business dimension (purple dots): expected impact for enhancing GS1's business value and business model
- Technology dimension (blue dots): expected impact for enhancing GS1 technology value and standards
- Center line: if research project is expected to enhance technology and business value



2.3.2 Continuous review and interaction with GS1

In addition to a scientifically rigorous approach aimed at academic publications, the Labs set a special focus to create direct value to GS1 and its stakeholders. The Labs work in a fact-based and design research driven approach that involves imagining, demonstrating, and experimenting with GS1 technologies and applications of the future. The results such as demos, publications, validation for business models, architecture blue prints as well as new hardware and software artifacts are shared and discussed with GS1 on a regular basis.

2.4 Dissemination activities

In addition to the two core activities of the labs for anticipating and shaping the future, the following section describes supporting activities for the collaboration of the Labs and GS1.

2.4.1 Dissemination within GS1

Research results of the labs are continuously disseminated within GS1 in different formats. The labs are present at key conferences and strategic sessions such as the GS1 Global Forum with an Auto-ID Labs Technology demonstration and active participation on Standards Events and working groups. The labs continuously publish an Auto-ID Lab White Paper series on the latest research results and also interact with GS1 MOs directly.

2.4.2 Internet of Things thought leadership

The Labs paved the way and helped coin the term Internet of Things from the beginning. The Labs are now focusing on re-claiming thought leadership by re-imagining the IOT and conducting the following measures to enhance the visibility for our research:

- Co-hosted events / conferences as publication outlets
- Outreach to a broader audience, academia, and cross industry community
- Various articles and interviews in the general press and TV
- A periodic “Inside the Labs” column contribution in RFID Journal – the premier news portal for the industry engagement of RFID and other object identification technology.
- Joint Auto-ID Lab book projects
- IOT Conference series

3 FLAGSHIP RESEARCH PROJECTS

3.1 GS1 Digital and Internet of Things Architecture (WP7)

3.1.1 Background / Summary

The GS1 architecture is a set of standards, interfaces, definitions, tools and services that enable a global interoperability for identifying, capturing, and sharing of product related information across companies and industries. It is a rich and powerful platform that boosts efficiency and enables an ecosystem of solution and service providers. However, the architecture today is very much focused on supply chain topics and simple data. It is critical, that the architecture evolves and addresses the following, potentially disruptive challenges and paradigm shifts:

- From pure B2B to B2B2C use cases
- From offline to online & mobile ("omni channel")
- From supply chain to extended stakeholders of member organizations (e.g. marketing and services)

With most distributed databases and computing resources moving to the cloud, there's also the opportunity for GS1 architecture to evaluate a cloud-based and linked data architecture as the next stage of its evolution.

3.1.2 Objectives

The goal of this project is to prepare the GS1 architecture for the aforementioned next generation challenges. In particular, the following objectives should be achieved:

- Developing a GS1 Digital technical architecture blueprint
- Extending existing GS1 EPCIS distributed data story towards a scalable Cloud-based system capable of linking IDs, attributes, and context-specific information
- Ensuring IOT thought leadership and community feedback for "Things on the Internet"
- Leveraging web standards for identifiers and linked data standards for accessing information

3.1.3 Selected Results

In close collaboration with the CTO office and industry engagement, the labs have launched GS1 Digital, a new flagship initiative to prepare the GS1 architecture for the online and mobile challenges. The labs have created a first position white paper on “ID on the web” and linked data technology to outline to the GS1 community the strategy, new business models, potential benefits as well as the technical foundations, including standardized technology from the World Wide Web Consortium (W3C).

The labs have also assisted the GS1 leadership team in explaining the vision of the GS1 Digital project to GS1 staff and have presented to interested groups within GS1 US, GS1 UK and GS1 Germany.

Initial experiments have considered applications for Consumer-to-Business scenarios and improving the online visibility / discoverability of products and retailers selling those products, regardless of whether the goods are sold online or on the high street in traditional retail stores.

The Global Product Classification (GPC) data has been converted from XML format into Linked Data RDF format, which makes it easier to query using tools such as the SPARQL query language. This enables new applications to help consumers find alternative products for a specific category, taking into account their individual context such as their dietary requirements and allergies, budgetary constraints, urgency, current location etc.

Moreover, the labs are developing a working platform to show and examine how we use GS1 keys, EPCs and product classification code such as GPC with EPCIS and semantic web technologies.

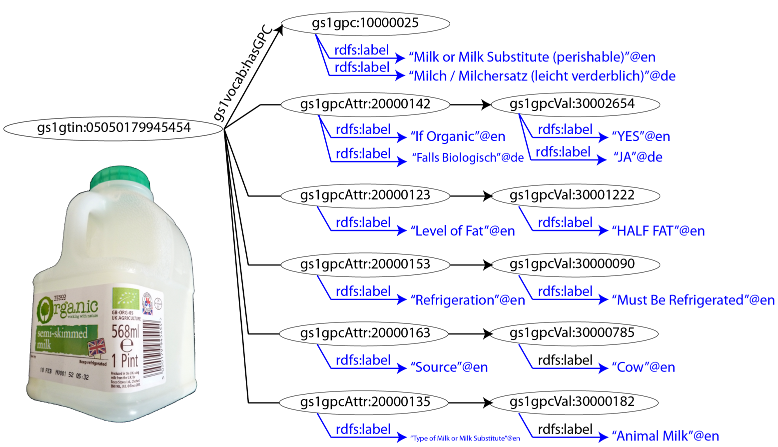
In terms of thought leadership and community feedback, the labs hosted a Big Data Conference at MIT, bringing together leading researchers and industry to discuss issues on the data explosion problem and analyzing the applicability and scope for cloud-computing solution techniques. Also, the labs were actively engaged in EU-funded projects such as IOT-A working on architecture reference models and basic building blocks that could be applied to the GS1 architecture.

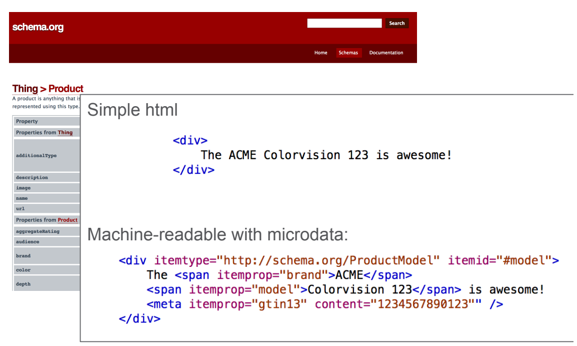
3.1.4 Impact to GS1

The architecture work is one of the most critical contributions of the labs, helping GS1 to re-invent itself from an architecture point of view and being able to scale and extend to new challenges. As an outcome, the labs will not only provide guidance for a next generation architecture blueprint, identify high value use cases, validate the results in pilots and create adoption tools, but also pave the way for new standards that would position GS1 strongly also in the online and mobile area.

3.1.5 Figures

The following figures illustrate examples and work in progress for the development and adoption of standardized web vocabularies to the GS1 System.





An illustration of the potential representation of GTIN identifiers, GPC bricks and GPC attribute-value pairs as Linked Data. Enabling Consumer-to-Business (C2B) and Business-to-Consumer (B2C) interactions with linked data.

Enhancing the web presentation to a human and machine-readable format by leveraging RDF, schema.org, microdata and other semantic web concepts.

Another example how a GS1 architecture can be used was demonstrated by the Japan Lab. The lab demonstrated a disaster relief system supply visibility system with a GS1 architecture in a disaster drill. GS1 keys, EPCs and product category IDs and EPCIS based cloud system were efficiently used to register, search, and aggregate relief supplies

3.1.6 Next steps

Next steps for this project include:

- On-going: Setting up a pilot for the B2C sandbox for selected GS1 Digital use cases
- On-going: Planning of the 2014 IOT Conference
- On-going: Development of a cloud-based framework for the Internet of Things
- 2012 – 2014: Publications and conference track at IoT 2012
- Mid 2014: White paper overview of developed architecture
- On-going: Report on immediate and future opportunities

3.2 Antenna-based sensing (WP2)

3.2.1 Background / Summary

There has been much research and development work of sensor-equipped RFID tags in the past few years. Most of the sensors that have emerged vary in price from $10-$100. Our goal has been to develop RFID tag-based sensors that cost little more than a passive RFID tag. This would enable the pervasive deployment of ultra-low cost sensors. For instance, these sensors could be deployed on individual milk cartons to monitor temperature and raise alarms in the cold chain. Similarly, such sensors could monitor cracks and moisture ingress in civil infrastructure.

The Auto-ID Labs have developed sensors that cause changes in temperature, moisture or other physical parameters to manifest as a sharp change in tag signal strength or frequency. Both these parameters can be seamlessly extracted from commercial RFID readers during tag interrogation in addition to the EPC number. This sensing concept thus extends RFID ‘Beyond Identification’ for sensing applications.

3.2.2 Objectives

This project explores the opportunities for developing low-cost, pervasive sensors in applications such as:

- Infrastructure Asset Management: Detection of cracks on concrete surfaces, monitoring the expansion of joints
- Environmental Sensing: Air quality, detection of pathogens and toxins
- Pest Control: Early warning sensors for termite, bed-bug infestations
- Retail: Detection of tampering with products
- Transportation: Tire pressure sensors, temperature alarms in engine parts
- Energy Efficiency: Sensors to detect fluid level, temperature and internal resistance of generator backup batteries
- Agriculture: Detection of ground moisture and concentration of nitrates and phosphates

3.2.3 Results / Findings to date

These sensors are poised to be one of the principal emerging areas of next-generation Auto-ID research:

- GE and Avery Dennison have recently commercialized an antenna-based sensor that monitors food quality[1].
- Low-cost, passive RFID sensing continues to be a topic of interest at premier academic conferences such as IEEE RFID and IEEE Sensors.
- Auto-ID researchers have recently participated in news[2] and magazine[3] articles, and panel discussions[4] to further discuss this technology.

Our recent development work includes the following:

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[1] http://www.investors.averydennison.com/phoenix.zhtml?c=97892&p=irol-newsArticle&ID=1517359&highlight=

[2] http://query.nytimes.com/gst/fullpage.html?res=9505EFD61531F930A35755C0A9649D8B63

[3] http://www.rfidjournal.com/articles/view?10762

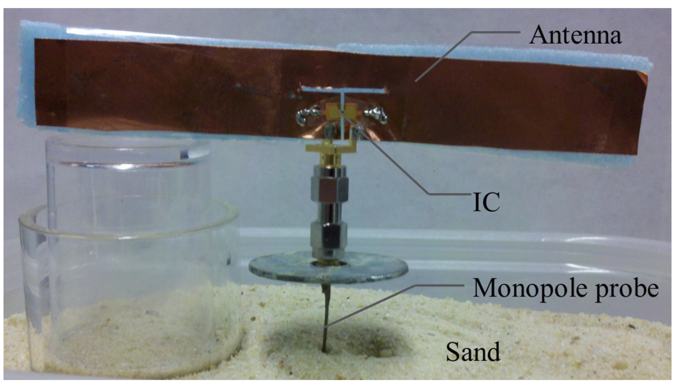
[4] http://www.meetup.com/MITRFID/events/102796202/

- Infrastructure Asset Management: Designed a crack sensor that can be directly painted on a structural surface. Developed sensors to monitor expansion joints on roads and railways.
- Energy Efficiency: Filed a provisional patent application for the fluid-level sensor. Initiated field test of sensor to monitor condition of wet cell batteries in data-centers.
- Agriculture: Developed a field moisture sensor that can reliably assess the state of soil as wet, moist or dry.

3.2.4 Impact to GS1

- *Thought leadership on the emerging internet of things*: Embedded field intelligence through pervasive sensing will be a key component of the Internet of Things. Innovative sensing techniques, such as antenna-based sensing, that take well established technologies such as RFID "beyond-identification" are particularly appealing. Research conducted by the Auto-ID Labs in this space will help cement GS1's position as a thought leader in technology development for the Internet of Things.
- *Expansion of application scope*: The adoption of Auto-ID sensing technology for diverse applications in agriculture, infrastructure monitoring, transportation and energy efficiency would strengthen GS1's leadership role in steering the growth and development of the Internet of Things. It would also provide an opportunity for GS1's standards and numbering schemas to be used for pervasive sensing applications.

3.2.5 Figures



Soil moisture sensor prototype. The probe penetrates the soil and depending on the moisture level changes the strength of response of the RFID tag to the reader. An increase or decrease in signal strength can thus be used to infer soil moisture.

A grid of RFID crack sensors painted on a structural surface. As a crack propagates, it severs some of the antennas. By detecting which tags have gone silent, it is possible to infer the length and direction of the crack propagation.

3.2.6 Next steps

- *Development of new sensor modalities:* Develop sensors for pest control particularly for the problem of early bed-bug infestation. Develop air quality sensors that will be able to detect mixtures of toxic gases like sulfur dioxide, nitrogen dioxide and carbon monoxide. Extend the design of the moisture sensor to detect nutrients like nitrates and phosphates.
- *Examination of new technologies:* Investigate potential application of chipless RFID and NFC for sensing. For instance, we have developed a chipless RFID version of our crack sensor. Develop a chipless RFID light intensity sensor to monitor indoor lighting.
- Publication of whitepapers, journal and conference articles

3.3 Meta-Materials (WP2)

3.3.1 Background / Summary

When standard RFID tags are placed directly on or in close proximity to metal objects, read ranges drop and read rates disappear because of tag detuning and destructive interference, preventing tags from receiving the power they need to operate and degrading the quality of any transmitted signals. Preemptive steps can be taken to preserve some modicum of performance, including retuning tag antennas through alterations to the antenna geometry and an increase to the overall size, and the reduction of destructive interference by increasing the distance between the tag and the conductive surface. While solutions such as 3D antennas and dielectric spacers have been used to improve on-metal performance, a new technology called meta-materials has the potential to boost tag performance by not only eliminating destructive interference, but introducing beneficial constructive interference in its stead. Meta-materials are synthetic materials built with specific electromagnetic properties in mind, properties often difficult to find in nature, but possible to fabricate in the lab. While in theory the ideal meta-material for RFID would be of an arbitrarily small thickness, in practice the meta-materials available today are still on the order of a few millimeters thick, often covering large surface areas, making them impractical for RFID inventory applications.

3.3.2 Objectives

This project aims to develop meta-materials to improve RFID tag performance on metal surfaces. Objectives include:

- Design and optimization of meta-material structures and their electrical properties for use with RFID, with the goal of 1mm thick meta-material substrates and associated RFID tag geometries.
- Fabrication and testing of meta-material prototypes
- Analysis of potential meta-material fabrication methods

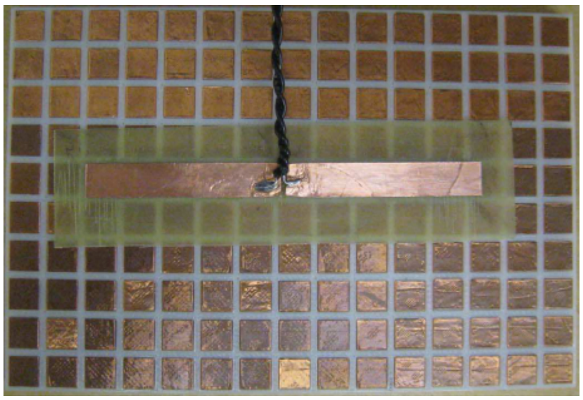
3.3.3 Results / Findings to date

To date, this study has evaluated a wide variety of meta-material structure designs, and experimentally validated the performance of several meta-material substrate prototypes, including a 5mm thick substrate which improved dipole antenna performance. Models developed over the course of this study have delineated several of the key material and structural factors that bound the performance of meta-materials for RFID. Output from the models and subsequent analysis have led to the design of even thinner substrates, which are central to the next steps. In addition, to tag substrates, meta-materials have also been developed to improve our ability to focus radio frequency signals, which can further enhance the performance of RFID systems.

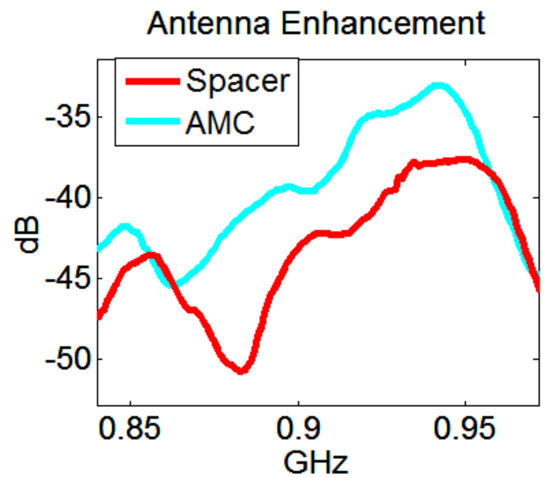
3.3.4 Impact to GS1

Expansion of application scope: The improvement in performance of Auto-ID technology will help drive adoption in otherwise unfriendly RFID environments, and strengthen GS1's leadership role in steering the growth and development of the Internet of Things.

3.3.5 Figures



A dipole antenna placed upon a periodic meta-material surface. The structure of the surface causes in-phase reflections and hence constructive interference that improves antenna performance.



A plot that compares the transmitted power of an antenna above the meta-material **(AMC)** surface, and one above a metal surface **(spacer)**. The transmitted power is much larger for the meta-material backed antenna, which translates into improved RFID read range and overall performance.

3.3.6 Next steps

- *Fabrication of Thinner Meta-material Prototypes:* New meta-material substrates have been designed that are poised to reach the goal of 1mm. Until recently, fabrication has proved to be a significant roadblock, but recent steps have been taken which should overcome these fabrication difficulties.
- *Examination of Meta-materials with Antennas:* In conjunction with simulation results, antennas will be designed to facilitate the operation of RFID tags for use upon the thinner meta-material substrates.
- *Extension to Meta-material Sensing:* The incorporation of meta-materials within RFID tag structures opens the door to further sensing studies.
- *RFID-friendly Metallic Objects:* Meta-materials can literally change the face of a particular object or structure by redefining the surface such that is it RFID friendly.
- Publication of journal and conference articles

3.4 EPC Calculus (WP3)

3.4.1 Background / Summary

Passive UHF RFID tags offer a typical read range of 3-4 m and thus enable inventory-tracking applications within indoor retail stores or distribution centers. However, the reliability of tracking must be carefully assessed due to the challenges associated with the nature of electromagnetic wave propagation and uncertainties in the RFID reader and tag systems. Questions such as: "did the tag enter or leave the dock?" are answered in an *ad hoc* way today. Similarly, the question of how to interpret intermittent tag reads – did the tag leave and come back, of did it merely fail to communicate with the reader? – is handled with ad hoc filters that is solved by embedded algorithms in the middleware software. Referred to as filters, these heuristic elements are tweaked by tedious manual intervention and are a key reason why RFID implementations today are expensive and, often, unreliable. These questions are becoming more complex as readers become more powerful with range and directional capabilities, and as mobile readers with real-time location systems become more prevalent. With the advent of the cloud these questions will need to be answered in a more systematic and repeatable way.

3.4.2 Objectives

This project develops embedded computing tools to maximize asset-tracking performance in indoor inventory management:

- Development of algorithms to reliably detect inventory and personnel movements in the environment and ensure reliable data interpretation from raw tag reads.
- Test algorithms in use cases.

3.4.3 Results / Findings to date

- Completed review of state of the art in RFID tag localization research.
- Initiated pre-study on machine learning and data aggregation techniques for RFID event detection.

3.4.4 Impact to GS1

RFID technology generates big data on track and trace operations. This big data is useful only when there are underlying algorithms which are capable of analyzing the data and uncovering valuable insights – reliably and accurately. This project will help promote GS1's role as a thought leader on big-data analysis and interpretation in field intelligence gathering.

3.4.5 Next steps

- Complete study on machine learning algorithms for RFID event detection
- Test algorithms in two test cases:
    - Construction worker safety: To detect events such as the onset of worker fatigue, injury and fall detection using RFID and sensing technology
    - Patient Scheduling: To measure typical wait times associated with different procedure rooms in a hospital and improve patient scheduling
- Publication of results in whitepapers and journal articles

3.5 Supply Chain Security (WP4)

3.5.1 Background / Summary

Object identification technologies have tremendous scope for automated anti-counterfeiting measures.

Counterfeiting of products is a significant problem in many industries and in some sectors, such as food, pharmaceuticals or aircraft parts and automotive parts, the distribution of counterfeit products or unauthorized parts can potentially endanger consumers, citizens and passengers. Through GS1 open standards such as EPC Information Services (EPCIS) it is possible to exchange very granular data about the observations of physical objects as they move through supply chains and to perform automated analysis of that data in order to identify any gaps or inconsistencies that might indicate that counterfeit products are being inserted into the supply chain.

The problem is compounded by the fact that major distributors of pharmaceuticals receive tens of thousands of cases of product each day, so it is important that they can routinely perform robust and consistent checking of traceability information in a manageable way that does not cause delays to their current receiving processes.

3.5.2 Objectives

The supply chain security project has a number of areas of focus, including:

1. Event-based traceability.
   - Using automated gathering and checking of fine-grained traceability information to detect counterfeits during distribution and stop them from reaching customers.
2. Security framework for distributed information networks
   - Recognizing that granular event data is highly commercially sensitive and can reveal information about production rates, inventory volumes, flow patterns and trading relationships, it is clear that event data should be shared only on a 'need to know' basis. This requires a highly granular security framework that can be used to restrict visibility to parties who were not on the actual chain of custody of a specific physical object.
3. Development of tamper-proof sensors for pharmaceutical drug integrity assurance

3.5.3 Results / Findings to date

- In both the areas of 1) Event-based traceability and 2) Security framework for distributed information networks, Auto-ID Labs researchers (specifically Mark Harrison [Cambridge] and Miguel Pardal [MIT]) are developing practical technical approaches and feeding these ideas directly into the GS1 Pedigree SCCS MSWG, in which they play an active technical leadership role.
- To address the data volume problem in the pharmaceutical supply chain, Auto-ID Labs researchers introduced the idea of Checking Services that could be run by trusted accredited third party service providers, enabling companies to outsource the burden of checking data. Via an Advance Shipment Notice or Dispatch Advice, a company could be notified about the unique identifiers (EPCs) of the products they can expect to receive. This list can then be sent to a Checking Service, together with a configured selection of tests to be performed on the traceability data for those identifiers. A Checking Service can then take responsibility for gathering the relevant data and performing the tests, providing the requestor with a convenient summary report that clearly indicates whether any identifiers failed any tests or generated warnings. The summary report can then be imported locally into receiving systems, so that they can quickly raise an alert if any goods received should be

refused or quarantined for further investigation. Full reports including all the relevant traceability information could also be generated on request.

3.5.4 Impact to GS1

With an increased emphasis on the out shoring of production facilities, supply chains today have become truly global. This trend poses two challenges: First, the verification of product authenticity, given that the transparency of object tracking data varies across geographical regions. Second, the big-data problem posed by the sheer volume of data that needs to be analyzed. Research in this project will provide GS1 with technological and analytical tools that maximize the chance of detecting spurious products in global supply chains. This will help develop improved confidence in the security measures provided by GS1's object identification and sensor technology.

3.5.5 Figures

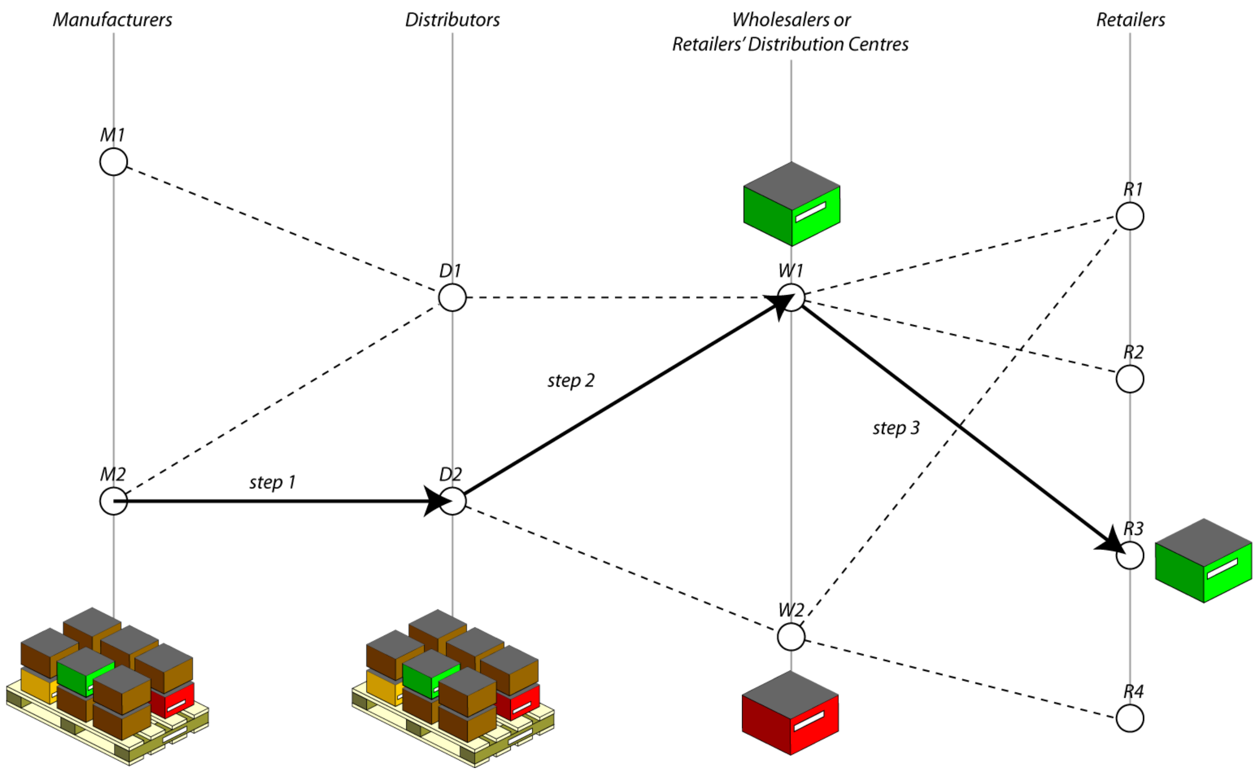
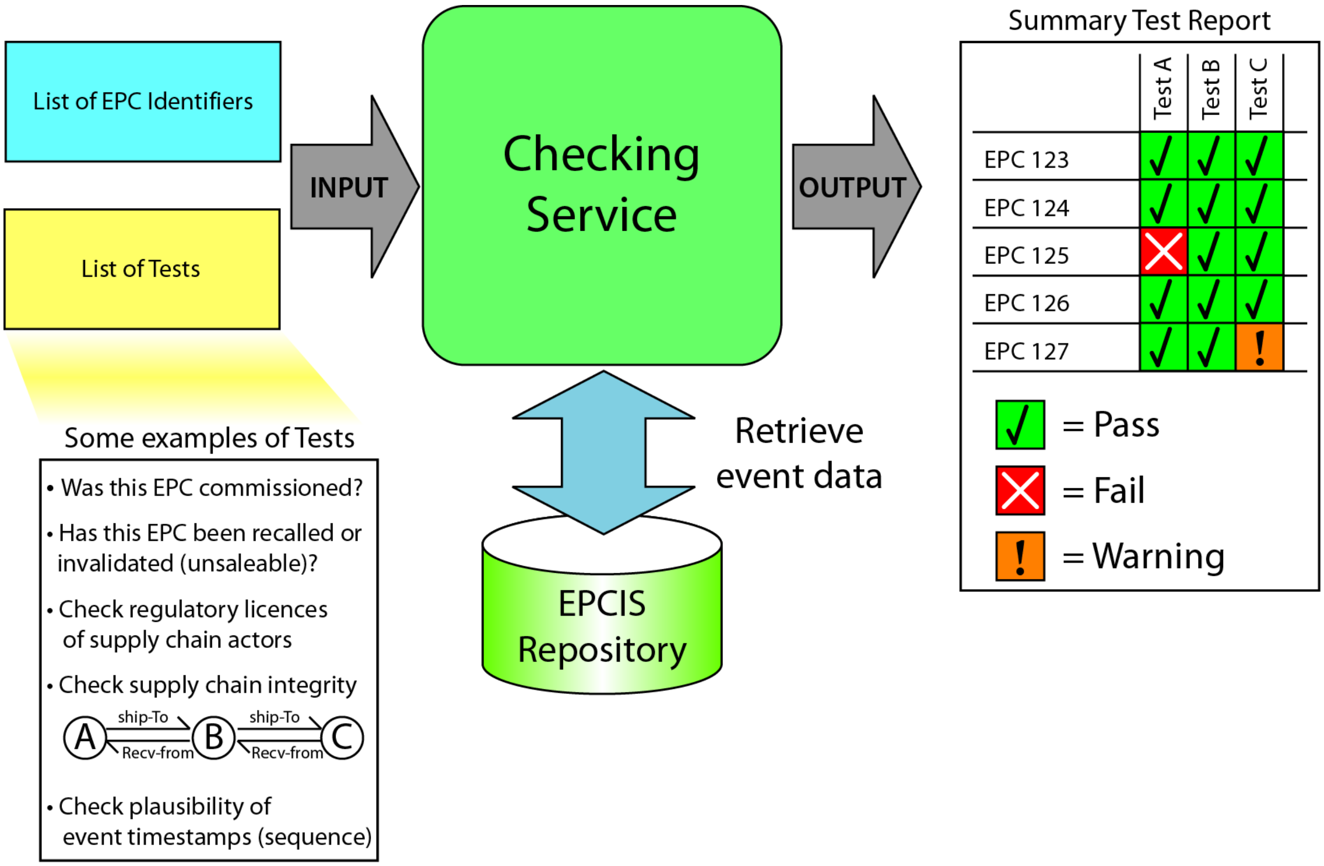


Illustration of a supply chain path and the challenge of managing access control when the actual path taken by an individual object is something that emerges over time, rather than being defined in advance. In this example, Distributor D2 receives a pallet, then breaks it down into cases that are sent to different wholesalers. It is important that retailer R3 and wholesaler W1 can see the traceability information for the green case but that they do not gain access to traceability information about the red case that they did not receive.



A conceptual illustration for an automated checking service for traceability data. Auto-ID Labs researchers are contributing technical leadership to the Pedigree SCCS MSWG to help with the standardization of the security framework, during the remainder of 2013.

3.5.6 Next steps

- Presentation of field test results from a tamper-proof sensor used for vaccine integrity monitoring in the pharmaceutical supply chain.
- Active contributions to GS1 standardization of the Security Framework (2013) and Checking Services (2014)

3.6 Standards scope expansion (WP5)

3.6.1 Background / Summary

It is important for GS1 to be kept informed of opportunities to amend existing standards and establish new ones. For instance, one outcome of the advent of several diverse object identification technologies is the scope for integrating pervasive sensing functionality. Mobile phones have several in-built sensors, there have been several instances of emerging NFC-based sensors and RFID vendors have been developing ICs with integrated temperature sensors and interfaces for additional sensors. These developments have resulted in modifications to existing wireless communication standards such as ISO 18000-6. With the advent of e-commerce and cloud computing, it is also important to consider the impact of linked data and semantic web technologies on GS1 standards and assess the potential of competing numbering schemas like Amazon's ASIN. The Labs suggest adaptation strategies for GS1 to meet these new changes.

3.6.2 Objectives

This project examines potential opportunities for GS1 to extend existing standards and develop new ones:

- For sensing paradigms developed by the labs
- For semantic web and linked data technologies

3.6.3 Results / Findings to date

New sensing techniques, such as low-rate RSSI modulation, developed at the Auto-ID Labs have good potential to convey precision sensor measurements at very low-cost. The communication protocol used to convey this sensor data overlays the Gen 2 standard and seamlessly extends it offering scope for a standards extension.

3.6.4 Impact to GS1

This project emphasizes the theme of "future proofing" and highlights application areas in pervasive sensing and e-commerce in which GS1 should adapt or evolve its standards in the face of emerging opportunities and threats.

3.6.5 Figures

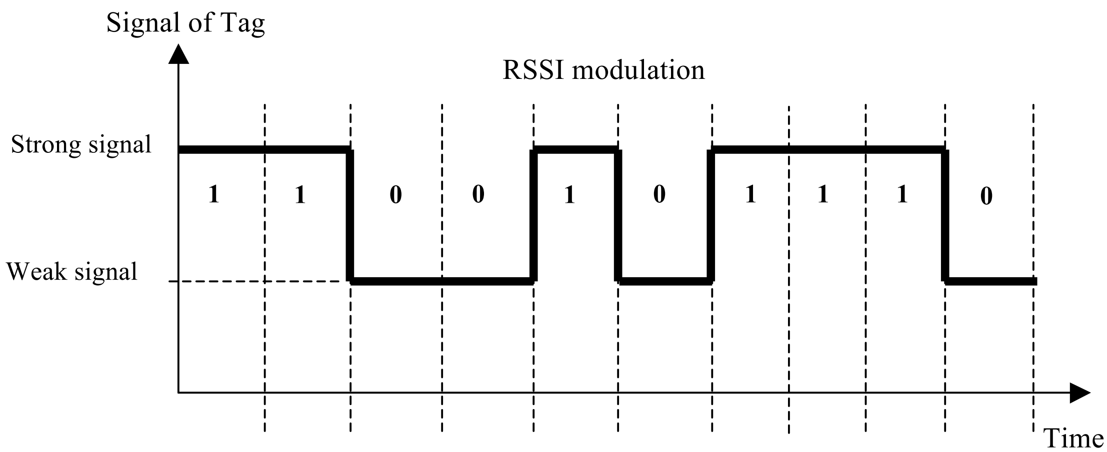


Diagram that illustrates the concept of low-rate RSSI modulation. A binary '1' is conveyed by having the tag respond with a strong signal while a '0' is conveyed by sending a weak signal. It's similar to Morse Code where changes in tag signal strength are used to communicate sensing information. Precision sensor data can be sent as a sequence of 1's and 0's. The sensing protocol overlays the Gen 2 protocol and seamlessly extends it.

3.6.6 Next steps

- Improve sensing technique for better read range and faster data transfer rate.
- Prepare whitepaper together with the GS1 Digital group to propose a standards framework for sensor discovery, sensor measurements, sensor modeling languages and alert services.

3.7 Visibility in a box (WP6)

3.7.1 Background / Summary

The set up of RFID, barcode and other object identification technologies is tedious and involves the system integration of hardware, software and database resources. This is often prohibitive to research groups and application engineers primarily interested in RFID tag data extraction and visualization. The success of NFC technology is in part due to the ease with which common users can interact with it via smartphones. It is important to emphasize the simplicity with which RFID and barcode scanner systems can be deployed via cloud-based data capture tools.

The Auto-ID Labs will work towards the development of a demonstration toolkit that will showcase the seamlessness between EPC or data-matrix capture and access by the web. For instance, an EPCIS demonstration toolkit will comprise of 2-3 RFID readers implementing the cloud-friendly reader protocols, a couple of hundred commercial RFID tags and a MiFi router. The ease with which data can be captured and accessed online along with the ease of inferring business intelligence such as determining the room or zone in which a product is currently located or the path traversed by an object based on successive reads at the different readers will be demonstrated.

3.7.2 Objectives

This project emphasizes the simplicity by which end users can access and visualize RFID tag data without incurring tedious hardware and software deployment setup costs:

- “Plug and Play” RFID system deployment
- Cloud-based service for RFID reader control and tag data acquisition
- Development of demo-kit
- Presentation at academic and industry forums

Compilation of report based on user feedback

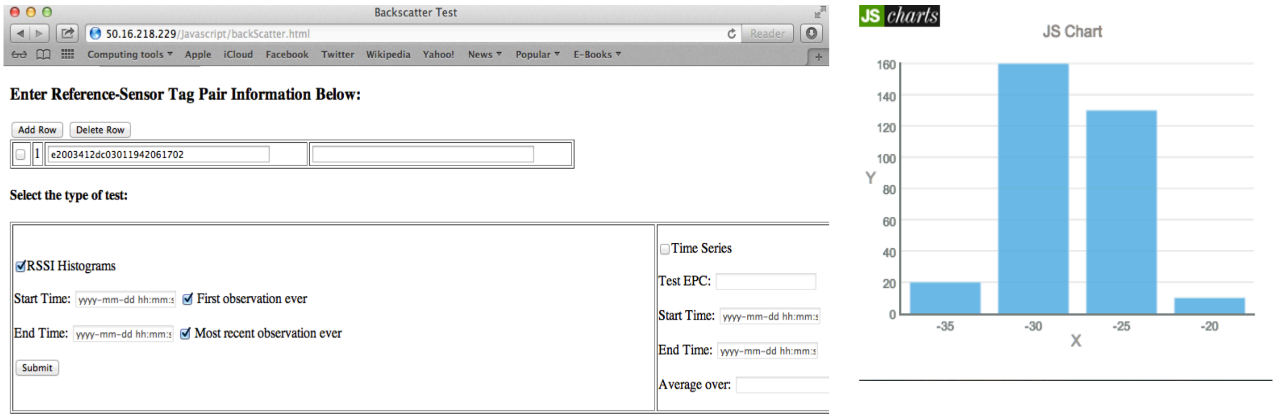
3.7.3 Results / Findings to date

The labs have developed a cloud-based tool that streamlines the process of UHF RFID tag acquisition and visualization. Rather than install a host of software interfaces, database management tools and third party graphing software, application engineers can directly use this tool to visualize tag information using their web-browser.

3.7.4 Impact to GS1

Business entities interested in evaluating object identification technologies for engineering applications may not have access to large investment capital for complicated hardware-software systems integration. Cloud-based tools that simplify the data acquisition and visualization process for the end users would help increase the consumer base for RFID and other object identification technologies. This would drive up sales volumes and encourage greater technology adoption.

3.7.5 Figures



A sample web-service. An Impinj RFID reader sends tag data to a cloud database. An end user enters a tag of interest and receives information about the number of times the tag was seen at a particular location and the corresponding strength of the tag's signal.

3.7.6 Next steps

- Expansion of web-service tools for location-based services, geo-spatial sensor data visualization.
- Distribution of web-services to interested parties for evaluation and comments.
- Design of API for third party application development.
- Preparation of whitepaper outlining cloud-based architecture and associated applications.

3.8 Digital Product Profiles (WP8)

3.8.1 Background / Summary

Following the Internet of Things paradigm, a bar code or EPC attached to a physical object can create a digital profile or virtual representation of the object that can be accessed over the Internet. Context specific information can then be related to this digital profile and managed. This profile can be cross-referenced with diverse sources of data almost all of which need to be accessible over the Internet.

Advances in linked data and IDs on the web enable the leap from today's internal and closed ID management to sophisticated digital product profiles that can be publicly shared and used as an access point for B2C interactions.

3.8.2 Objectives

This project explores the business opportunities and challenges that emerge from digital product profiles:

- Explore new opportunities on ID management and data mapping
- Consider relation of serialized IDs (e.g. EPC), class level IDs and consumer-facing IDs
- Evaluate opportunities of digital product profiles in linked-data scenarios
- Also look at high-value post-purchase scenarios (e.g. profiles as point of sale or point of service)
- Ensuring authenticated and verifiable data in collected product profiles

3.8.3 Results / Findings to date

The labs conducted a pre-study on data management approaches that leverage data inheritance through tree structures for low-effort maintenance while supporting rich product profile data (e.g. images and videos). Also, the study included an identification of opportunities for linking data provided by manufacturers (e.g. instruction manuals) to digital product profiles. Finally, an overview of the opportunities for post-purchase services that could be provided through a digital product profile have been evaluated.

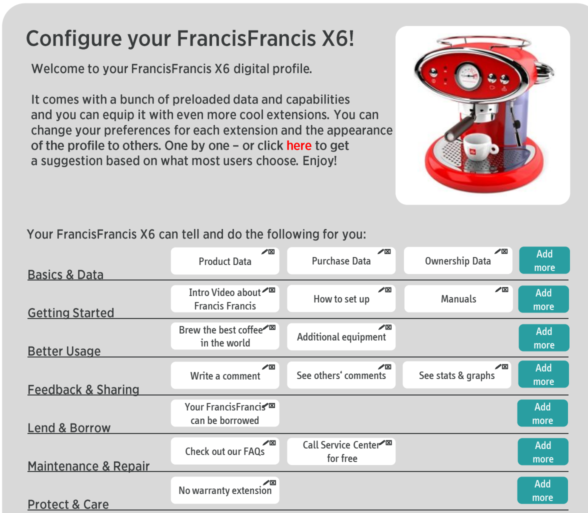
In addition, we have been given first insights by qipp.com, a spin-off of the Auto-ID Lab HSG / ETH which is validating a number of these approaches with customers in Switzerland for consumer facing IDs and an associated resolution infrastructure.

3.8.4 Impact to GS1

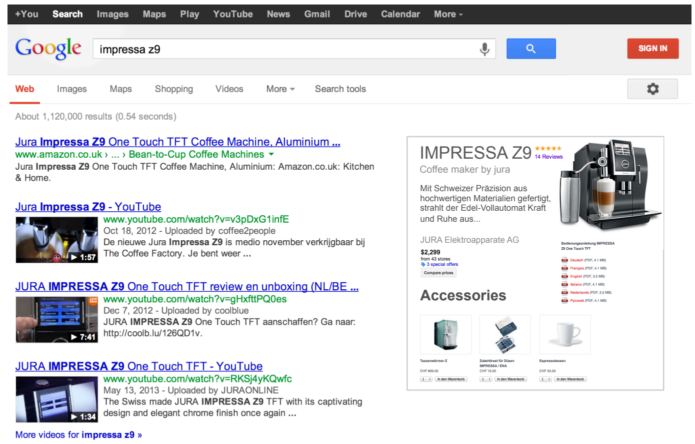
ID management is one of the key areas for GS1. This project will help understanding the opportunities of using digital product profiles in conjunction with linked data on the web as a powerful tool to boost sales and enable comprehensive analytics.

3.8.5 Figures

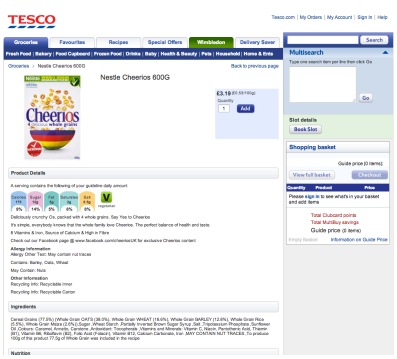
Example of a digital product profile that can consist of trusted manufacturer data and services as well as publicly available consumer feedback ratings and information from the feasibility study:

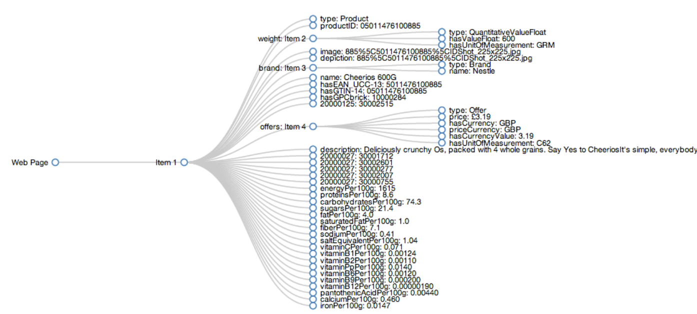


Example of a Digital Product Profile by qipp.com. With ID on the web and linked data, the digital product profile becomes an anchor point for consolidating consumer generated data and trusted manufacturer data. Thanks to GS1 standards, manufacturer information and services can be authenticated and verified.



Example for improved Search Engine Result Pages (SERP). Digital Product Profiles will become additional Point-of-Sale and Point-of-Service entry points for consumers. An example shows this for a coffee maker on the right side where information is consolidated and accessories and services can be directly purchased.





By including Linked Data markup within web pages for products, structured data about the product (e.g. nutritional information, weight) and the offer (e.g. price, availability) can be made available to search engines and mobile apps.

3.8.6 Next steps

- Mid 2013: White paper on opportunity and proposed model
- Mid 2014: Pilot with selected GS1 MOs and customers
- Mid 2014: Evaluation report

3.9 Digital Accounts (WP9)

3.9.1 Background / Summary

Retail is being fundamentally reshaped with the entrance of new small-lot manufacturers – such as organic produce vendors – and different retail channels – such as Internet retailers with business models ranging from subscription to flash-sales. In short, a new, brash class of GS1 users is emerging. To serve this new group, GS1 should explore new approaches to serving these customers. Examples range from trusted management of meta-data to self-service issuance of GS1 keys to new business models based on standardized data for online and offline retailing. This project, in other words, will be a continuance of earlier research on B2C, mobile commerce and trusted data targeted at making GS1 more attractive for the new customer types.

3.9.2 Objectives

Enabling adoption for reshaped retail channel and new customer types

- Prepare for the reshaping of the retail channel due to dissolving boundaries between online and offline shopping and new types of small-lot manufacturers.
- Continued research on B2B2C, mobile commerce and trusted data

3.9.3 Results / Findings to date

A light-weight and highly efficient protocol for digital receipt has been developed that can be easily implemented by traditional POS systems as well as newly deployed tablet-based systems. It serves as a basis for enriching purchase data with GS1 identifiers and thus providing mobile users with a direct link towards a highly attractive representation of the products on the receipt as well as connecting consumers to existing meta-data.

Dashboards based on GS1 identifiers and GPC can provide instant value to the new customer types. We started a project with a small lot manufacturer and specialty retailer to show how real-time analytics can be made accessible for everyone with high granularity by linking POS data with mobile loyalty cards. The dashboard provides instant value by providing consumer insights and allows for a measurement of the adoption of newly introduced products in comparison to benchmarks and to detect changes in sales performance in real-time so that all levels in the supply chain are able to respond quickly.

In addition, we studied social media engagement measurement for retailers and brands. We developed an evaluation framework that allows companies to perform social media analytics through continuous monitoring of the content and activities on their social media marketing channels, and to measure the effectiveness of social media utilization for marketing purposes.

3.9.4 Impact to GS1

The research results of the project provide GS1 with powerful tools and insights to drive adoption among new customer types. The outcomes of this project illustrate which GS1 standards and procedures have to be extended and in which way, in order to provide instant value for the new customer types, as well as providing guidance about how to leverage trends such as mobile users to further accelerate the benefits of adopting GS1 standards versus relying on private or competing symbologies.

3.9.5 Figures

Examples from a study with an Austrian retailer (that also serves small-lot self-branded products) to show the value of digital receipts in a real-world context:

Enabling consumer big data and analytics with digital receipts for online and offline purchases. Mobile apps can collect itemized receipts that are human-readable and machine-readable.

Enables cross-channel analytics for retailers, brands, and consumers. Example shows a real-time dashboard for measuring product loyalty for a specific GTIN in comparison to competing products in a particular GPC Brick.

3.9.6 Next steps

- Mid 2013: Architecture and summary White Paper
- Mid 2014: Pilot with selected GS1 MO/ customers
- Mid 2014: Evaluation report

3.10 In-store promotions (WP10)

3.10.1 Background / Summary

In an increasingly crowded marketplace, retailers need new innovative ways of reaching out to their consumers. Currently, with regards to promotions, the paradigm is “all customers treated the same, promoted the same products, given a monetary incentive (discounts), and given this incentive by mail at home”. We will deploy smartphones to test new mobile loyalty concepts and to investigate techniques that would enhance and encourage the in-store shopping experience. Examples include the evaluation of applicability of proven online concepts to physical stores (e.g. Flash sales based on NFC) and location/context-based sales.

The basic idea of the new approach could be summarized as leveraging mobile technology to address new variables of the classical promotional paradigm:

Better promotion = Individual Customer x Individual Product x Individual Incentive x Context (e.g. place, time)

The sales performance will be compared to today's dominant approach of the same static promotions given to all customers. Our work aims to help the existing community to stay competitive in a currently changing market by exploring new techniques of promotions. Proven promotional concepts from the online world will be adapted via smartphones into the physical stores such as flash couponing, social-influence based promotions, context-based promotions.

3.10.2 Objectives

- Summary report outlining flash couponing, social-influence and other techniques that encourage the in-store shopping experience for consumers
- Implementation of pilot project in retail stores and involve MOs
- Report outlining the success of these techniques and highlighting future opportunities

3.10.3 Results / Findings to date

We are currently running online studies that examine to what extent the presentation of a product’s popularity information could influence a consumer’s purchasing decision, as a proof of concept for a field deployment in a physical store. An initial study found that for two products of similar popularity (operationalized as the sales rank), by simply changing the presentation and metric of the rank-related information, it was possible to nudge consumers to choose the less popular product. This first result implies that non-monetary promotions like popularity can be effective, and furthermore, with the right framing, they can also nudge consumers to the different classes of products along the long tail of sales.

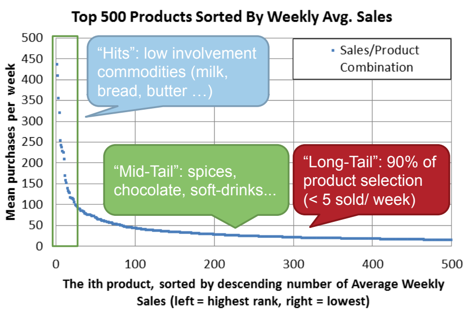
In parallel, we are running a pilot study with an Austrian retailer with a field deployment of a mobile app in order to determine which products are of interest in a mobile recommendation system context, and which products and consumer clusters might be prone to social-influence based promotions (such as the observational learning technique, which has been used with great success in e-commerce). The findings would strongly bridge the gap between marketing in the online world (previously dominated by e-commerce) and the offline world.

3.10.4 Impact to GS1

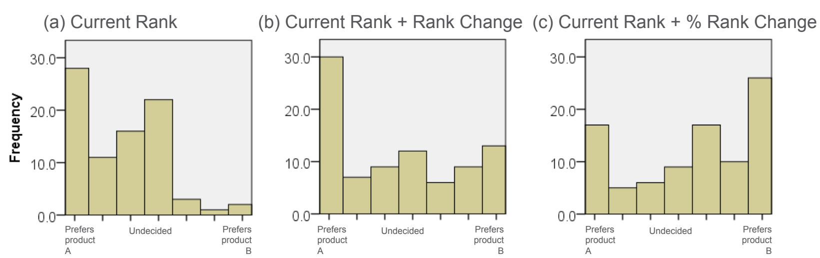
The results of this project show how to bring proven eCommerce concepts to the physical world. This enables new business models thanks to better data and standards. Also, it shows how mobile users can be integrated in the communication loop by retailers to shift from pure price comparison and "showrooming" towards driving real value and boosting sales.

3.10.5 Figures

Results on a study for using popularity metrics to influence consumer behavior towards mid-tail products as well as an application of e-commerce principles of observational learning and popularity information to a physical retail store are shown below:



Example distribution of products in a physical retail store. Our initial study focused on nudging people for mid-tail products.



By simply changing the presentation and metric of the rank-related information, it was possible to nudge consumers from product with actual sales rank of #50 towards a product ranked #51 that had a higher margin.

3.10.6 Next steps

The results of the online studies would be extended in future work and the insights would be used to refine our pilot app with our Austrian retailer partner. Furthermore, the results of the Austrian pilot study would be used to revise our concepts and technology for a wider deployment with other stores and retailers.

4 ANNEX

4.1 Publication list

MIT (2012 - June 2013):

- Bhattacharyya, R., Kalansuriya, P., Sarma, S. E. (2013). An antenna-based RFID expansion joint monitor. To be presented at the IEEE International Symposium on Antennas and Propagation: Special Session on Advances in RFID Sensing, 2013.
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- Kranz, M., Murmann, L., Michahelles, F., Research in the large: Challenges for large-scale mobile application research: a case study about NFC adoption using gamification via an App store, International Journal of Mobile Human Computer Interaction, 2013. .
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- Yuki Sato, Yuki Igarashi, Jin Mitsugi, Osamu Nakamura, Jun Murai "Identification of Missing Objects with Group Coding of RF tags", IEEE RFID 2012, pp. 95-101, April 4, 2012
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- Suho Jeong, Seong Hoon Kim, Minkeun Ha, Taehong Kim, Jinyoung Yang, Nam Giang and Daeyoung Kim, "Enabling Transaparent Communication with Global ID for the Internet of Things," International Workshop on Extending Seamlessly to the Internet of Things (esIoT), Palermo, Italy, Jul. 4-6, 2012
- Kiwoong Kwon, Minkeun Ha Taehong Kim, Seong Hoon Kim, Daeyoung Kim, "The Stateless Point to Point Routing Protocol based on Shortcut Tree Routing Algorithm for IP-WSN", The 3rd International Conference on the Internet of Things (IoT 2012) Wuxi, China, October 24-26, 2012
- Giang Nam, Minkeun Ha, and Daeyoung Kim, "Web-enabled Smart Tags for Physical Things," poster paper in The 3rd International Conference on the Internet of Things (IoT 2012) Wuxi, China, October 24-26, 2012
- Seong Hoon Kim, Janggwan Im, Jaewook Byun, Kwangkook Lee, Daeyoung Kim, Cedric Crettaz, Sebastien Ziegler," Enabling A Global Infrastructure for Physical Information Sharing over the Internet," poster paper in The 3rd International Conference on the Internet of Things (IoT 2012) Wuxi, China, October 24-26, 2012

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- Thomas Kaufmann, Damith C. Ranasinghe, Ming Zhou, and Christophe Fumeaux, "Wearable Quarter-Wave Folded Microstrip Antenna for Passive UHF RFID Applications," International Journal of Antennas and Propagation, vol. 2013, Article ID 129839, 11 pages, 2013. doi:10.1155/2013/129839
- D. C. Ransinghe, R. Shinmoto Torres, K. D. Hill, and R. Visvanathan, "A Movement Sensor System to Identify Bed Exits: A Pilot Study,"(accepted 17 Jul. 2013)

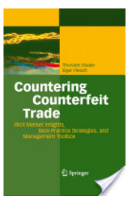
- D. C. Ranasinghe, R. Shinmoto Torres, K. D. Hill, and R. Visvanathan, "Low Cost and Batteryless Sensor-Enabled Radio Frequency Identification Tag Based Approaches to Identify Patient Bed Entry and Exit Posture Transitions," Gait & Posture (accepted).
- T. Sanchez, D. C. Ranasinghe, M. Harrison and D. McFarlane, "Adding sense to the Internet of Things: An architecture framework for smart objects," Personal and Ubiquitous Computing, Vol. 16, Issue 3, pp. 291-308, 2012
- R. L. Shinmoto Torres, D. C. Ranasinghe, Q. Shi and A. Sample, "Sensor enabled wearable RFID technology for mitigating the risk of falls near beds," Proceedings of the IEEE RFID (IEEE RFID 2013), Orlando, Florida, USA, 30 April – 2 May 2013 (nominated for best paper award).
- D. C. Ranasinghe, R. L. Shinmoto Torres, and A. Wickramasinghe, "Automated activity recognition and monitoring of elderly using wireless sensors: research challenges," 5th IEEE International Workshop on Advances in Sensors and Interfaces (IWASI 2013), Bari - Italy, 13-14 June, 2013.
- O. Kavehei, C. Hosung, D. C. Ranasinghe, and S. Skafidas, "mrPUF: a Memristive Device Based Physical Unclonable Function," IEEE International Symposium on Circuits and Systems, Beijing, China, 19-23 May, 2013.
- D. C. Ranasinghe, N. J. Falkner, C. Pan, and H. Wu, "Wireless Sensing Platform for Remote Monitoring and Control of Wine Fermentation," The 8th IEEE International Conference on Intelligent Sensors, Sensor Networks and Information Processing (IEEE ISSNIP), Melbourne, Australia, 2-5 April, 2013 (accepted).
- M. K. Kopaei, A. Mehdizadeh, D. C. Ranasinghe and S. Al-Sarawi, "A novel hybrid approach for wireless powering of biomedical implants," The 8th IEEE International Conference on Intelligent Sensors, Sensor Networks and Information Processing (IEEE ISSNIP 2013), Melbourne, Australia, 2-5 April, 2013
- J. Ma, Q. Z. Sheng, D. C. Ranasinghe, J. M. Chuah, and Y. Wu A, "Unified Framework for Distributed Managing Uncertain Data in RFID Traceability Networks," The 13th International Conference on Web Information Systems Engineering (WISE 2012), Paphos, Cyprus, 28-30 November, 2012.
- D. Ness, J. Swift, D. C. Ranasinghe, K. Xing, V. Soebarto and M. Terziovski, "Smart steel: new paradigms for the reuse of steel enabled by digital tracking and modelling," Proceedings of International Greening of Industry Network Conference (GIN 2012), Sweden, 21-24 October, 2012.
- R. Visvanathan, D.C. Ranasinghe, N. Mahajan, R.L. Shinmoto Torres, L. Steward, A. Khoo, D. Gentilcore, S. Hoskins, M. Tremaine and K. Hill, "AMBIGeM: Innovative use of technology to monitor humans and reduce risk of falls in acute care" 5th Biennial Australian and New Zealand Falls Prevention Conference (ANZFPS 2012), South Australia, 28-30 October 2012.
- D. C. Ranasinghe, R. L. Shinmoto Torres, K. Hill and R. Visvanathan, "Towards falls prevention: A wearable wireless and battery-less sensing and automatic identification tag for real time monitoring of human movements," 34th Annual International IEEE EMBS Conference of the IEEE Engineering in Medicine and Biology Society (EMBS 2012), San Diego, California, USA, 28 Aug – 1 Sept, 2012.
- R. Visvanathan, D. C. Ranasinghe, R. L. Shinmoto Torres, and K. Hill, "Framework for Preventing Falls in Acute Hospitals using Passive Sensor Enabled Radio Frequency Identification Technology," 34th Annual International IEEE EMBS Conference of the IEEE Engineering in Medicine and Biology Society (EMBS 2012), San Diego, USA, 28 August – 1 September, 2012.
- Y. Wu, Q. Z. Sheng, D. C. Ranasinghe, and L. Yao. "PeerTrack: A Platform for Tracking and Tracing Objects in Large-Scale Traceability Networks," Proceedings of the 15th International Conference on Extending Database Technology (EDBT 2012), Berlin, Germany, 26-30 March 2012.

4.2 Links and further reading

4.2.1 Web Pages

Auto-ID Labs Global	http://www.autoidlabs.org/
Auto-ID Lab MIT	http://web.mit.edu/
Auto-ID Lab Cambridge	http://www.autoidlabs.org.uk/
Auto-ID Lab St. Gallen / ETH	http://www.autoidlabs.ch/
Auto-ID Lab Kaist	http://resl.kaist.ac.kr/
Auto-ID Lab Fudan	http://www.autoidlab.fudan.edu.cn/
Auto-ID Lab Keio	http://www.autoidlab.jp
Auto-ID Lab Adelaide	http://cs.adelaide.edu.au/users/autoidlab/index.php

4.2.2 Auto-ID Labs Published Books



Countering Counterfeit Trade
Illicit Market Insights, Best-Practice Strategies, and Management Toolbox
Authors: T. Staake, E. Fleisch
Springer-Verlag Berlin and Heidelberg GmbH & Co. KG, 2010
ISBN 978-3642095627

The Internet of Things
First International Conference, IOT 2008
Editors: C. Floerkemeier, M. Langheinrich, E. Fleisch, F. Mattern, S. E. Sarma
Springer-Verlag, Lecture Notes in Computer Science, 2008
ISBN 978-3540787303

RFID Technology and Applications
Editors: Stephen B. Miles, Sanjay E. Sarma and John R. Williams
Cambridge University Press, 2008
ISBN 978-0-521-88093-0

Networked RFID Systems and Lightweight Cryptography:
Raising Barriers to Product Counterfeiting
Editors: Peter H. Cole, Damith C. Ranasinghe
Springer-Verlag Berlin and Heidelberg GmbH & Co. KG, 2010
ISBN 9783642090790

4.2.3 Auto-ID Labs Published White Papers

All white papers are available electronically from http://www.autoidlabs.org

1. What is the Internet of Things? - An Economic Perspective
2. Evaluation Framework for Social Media Brand Presence
3. Object Circles: Modelling physical objects as social relationships
4. The scanner at your finger tips – analysis of the effective of the scan mouse device
5. Collision Recovery Receiver for EPC Gen2 RFID Systems
6. A Configurable RFID Sensor Tag Baseband Conforming to IEEE 1451.7 Standard
7. Usage Analysis of a Mobile Bargain Finder Application
8. Total lifecycle information sharing system of consumer electronics with globally unique identifier
9. Increasing Brand Attractiveness and Sales through Social Media Comments on Public Displays – Evidence from a Field Experiment in the Retail Industry
10. Social Media Integration into the GS1 Framework
11. RFID-Enabled Shelf Replenishment with Backroom Monitoring in Retail Stores
12. Positioning RFID Technology into the Innovation Theory Landscape: a Multidimensional Perspective Integrating Case Study Approach
13. Product Empire - Serious play with barcodes
14. The not so unique Global Trade Identification Number - Exploring inconsistencies in online product information sources
15. my2cents - Digitizing consumer opinions and comments about retail products
16. Evaluation of 1D Barcode Scanning on Mobile Phones
17. The Potential of the EPC Network to Monitor and Manage the Carbon Footprint of Products II
18. Supply Chain sensor support by integrating the OGC Sensor Web Enablement and the EPC Network architectures
19. Toward Designing Provably Secure Cryptographic Protocols for RFID Tags
20. Efficient Novel Anti-Collision Protocols for Passive RFID Tags
21. Sensor Profile Requirements for Sensor Network Capability Information in the EPCglobal Network
22. EPCIS-based Supply Chain Visualization Tool
23. Simulation Study on the Effect of Sensor Information in Supply Chains of Perishable Goods

24. The Potential of the EPC Network to Monitor and Manage the Carbon Footprint of Products
25. Supporting a Mobile Lost and Found Community
26. APriori: A Ubiquitous Product Rating System
27. RF Tag with RF and Baseband Communication Interfaces for Product Lifecycle Management
28. MobileIoT Toolkit: Connecting the EPC Network to Mobile Phones
29. Anti-Collision Issue Analysis in Gen2 Protocol - Anti-collision issue analysis considering capture effect
30. A Mutual Authentication Protocol for RFID Using IDEA
31. Why RFID Adoption and Diffusion takes Time: The Role of Standards in the Automotive Industry
32. RFID, Privacy and the Perception of Risk: a strategic framework
33. Lifecycle ID and Lifecycle Data Management
34. Data Synchronization Specification
35. Track and Trace Case Studies Report
36. Automatic ID Systems: Enablers for Track and Trace Performance
37. EPC Identifiers for aerospace
38. Operating Appliances with Mobile Phones –Strengths and Limits of a Universal Interaction Device
39. Features, Identity, Tracing, and Cryptography in Product Authentication
40. Adoption and Diffusion of RFID Technology in the Automotive Industry
41. Technology Selection for Identification Applications
42. Efficient frequency sharing of baseband and subcarrier coding UHF RFID systems
43. Making Radio Frequency Identification Visible – A Watchdog Tag
44. Design and Testing of A Small Passive UHF RFID Tag for Metallic Item Identification
45. A Simple Dual-frequency Antenna Design for RFID Tag
46. 4.7pJ/pulse 7th Derivative Gaussian Pulse Generator for Impulse Radio UWB
47. Adiabatic Circuit Applied for LF Tag
48. A Low Voltage Low Power RF/Analog Front-end Circuit for Passive UHF RFID Tag
49. On-Chip Antenna Designs for UHF RFID
50. Anti-collision Scheme Analysis of RFID System
51. Architecture Development for Sensor Integration in the EPCglobal Network
52. Publishing and Discovering Information and Services for Tagged Products

53. Probabilistic Approach for Location-Based Authentication
54. The EPC Business Collaboration Framework
55. The Dual Ownership Model
56. Facilitating RFID Development with the Accada Prototyping Platform
57. Use of the Shrinking Generator in Lightweight Cryptography for RFID
58. An Authentication Framework for Integrating RFID Systems
59. Connecting Mobile Phones to the Internet of Things: A Discussion of Compatibility Issues between EPC and NFC
60. Wireless Sensor Networks
61. Enhancing Security of EPCGlobal Gen-2 RFID against Traceability and Cloning
62. Enhanced Mutual Authentication Protocol for Low-cost RFID
63. RFID Tag-Reader Mutual Authentication Scheme Utilizing Tag\'s Access Password
64. Security Assessment of EPCglobal Architecture Framework
65. Managing Risk Perceptions of RFID
66. EPC System for Safe & Secure Supply Chain and How it is applied
67. Security Scheme for RFID Tag
68. Scheme of Truly Random Number Generator Application in RFID Tag
69. Definition of Terms used by the Auto-ID Labs in the Anti-Counterfeiting White Paper Series
70. Elliptic Curve Cryptography
71. Security in Low Cost RFID
72. A Low Cost Solution to Authentication in Passive RFID Systems
73. Strengthening the Security of Machine-Readable Documents
74. Security and Authentication Primer
75. Improving the safety and security of the pharmaceutical supply chain
76. The Potential of RFID and NFC in Anti-Counterfeiting
77. Product Specific Security Features Based on RFID Technology
78. From Identification to Authentication
79. One Time Codes
80. Flagship Project Anti-Counterfeiting & Secure Supply Chain
81. Applying Auto-ID to the Japanese Publication Business
82. An Adoption Strategy for an Open RFID Standard - Potentials for RFID in the Automotive Aftermarket

83. The impact of Auto-ID technology on process performance –RFID in the FMCG supply chain
84. RFID Data Capture and its Impact on Shelf Replenishment
85. Physics and Protocols in Radio Frequency Identification
86. From Operations to Strategy: The Potential of RFID for the Automotive Industry
87. RFID—The Opportunity for Logistics Service Providers
88. Auto-ID on the Line: The Value of Auto-ID Technology in Manufacturing
89. Executive Briefing. Public Policy: Understanding Public Opinion
90. RFID Systems, Security & Privacy Implications
91. Methodologies for Integrating Auto-ID Data with existing Manufacturing Business Information Systems
92. Towards an Approach to «Intellectual Property»
93. Multi-Band, Low-Cost EPC Tag Reader
94. Towards RFID Peformance Benchmark Tests
95. The University of Cambridge Auto-ID Centre from 2001–2003
96. Integration of Auto-ID Tagging System with Holonic Manufacturing Systems
97. The Virtual Electronic Product Code