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A case of study for embedding RFID tags in precast concrete

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Introduction

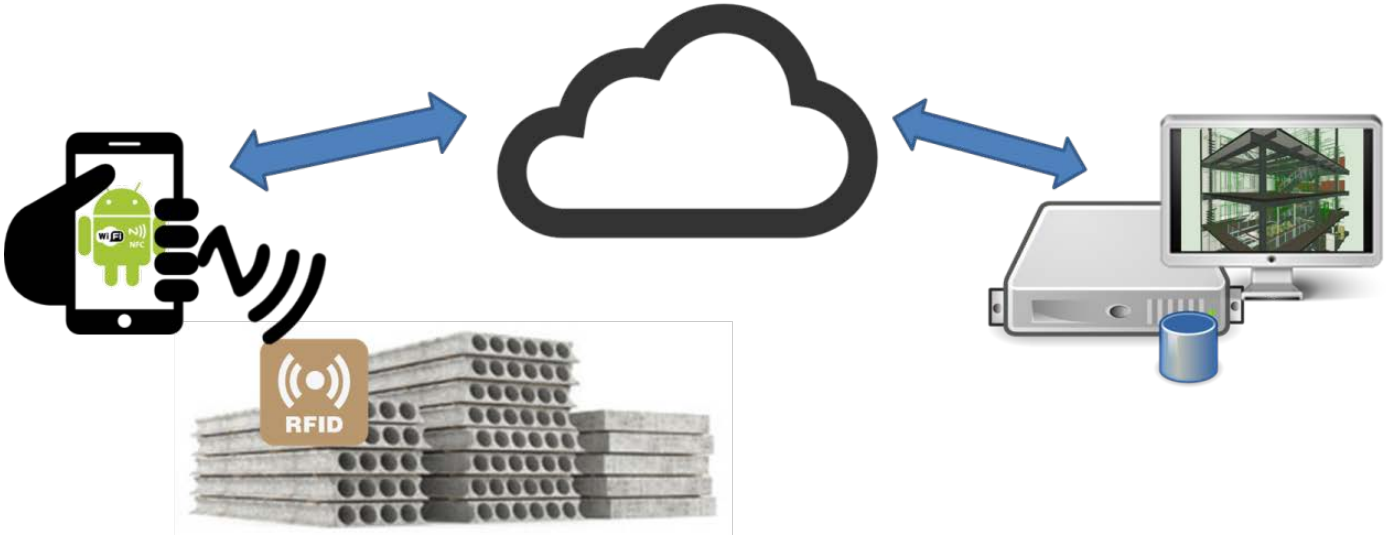
- When a concrete structure is built, the availability of all the information regarding its design and construction phases is important along the structure's lifetime

- GOAL: Storing this information into the pieces themselves to afterwards obtain all this information in-situ through a long-term labeling method

Introduction

- Long-term labeling method using embedded electronic tags storing:
  - Identification of pieces
  - Dates (construction, transportation , mounting)
- Additional information:
  - Building information model linkage (BIM)
  - Contractor data —e.g. traceability for the materials
  - Characteristics of construction processes
  - Etc …

Introduction: Environment



Introduction: SoA

- Recent studies have suggested the possibility of embedding electronic tags in concrete
  - E.g NIST study on RF signal attenuation in different concrete and precast pieces
- Advantages of combining radio-frequency identification (RFID) tags with building information models (BIM) systems
- As well as its benefits in production chains

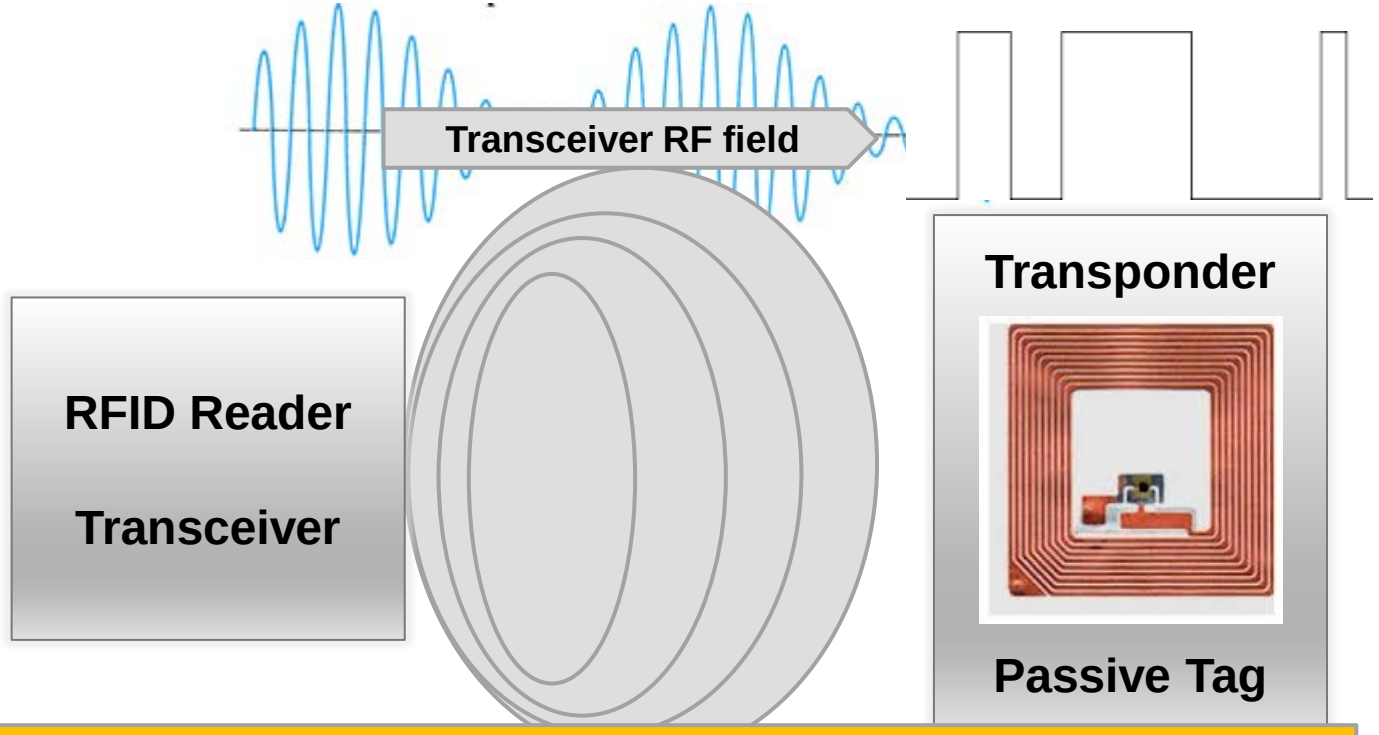
Why RFID?

- Radio Frequency Identification is a technology targeted at identifying and/or communicating with remote devices — tags — in a contactless manner

How RFID works?

- RFID tags and readers are electronic devices composed of
  - (i) a low-power microcontroller unit (MCU) or a custom integrated circuit designed
  - (ii) a radio transponder
  - (iii) an antenna and matching network tuned to the operating frequency
- Common frequency bands
  - Low Frequency (LF): normally 125 KHz or 134 KHz
  - High Frequency (HF): most often 13.56 MHz.
  - Ultra-High Frequency (UHF) band: 868 MHz (Europe), 915 MHz (United States) or 960 MHz (Japan)

Passive RFID tags



As these tags are powered solely by the reader, their lifespan is much longer and thus can be used in long-term applications

Passive Tag modules the transceiver signal for returning stored data

Near field communication - NFC

- It is a subclass of the RFID technology operating in the HF band (13.56 MHz)
- NFC enables two-way contactless communication in short distances (6-7 cm)
- NFC tags can be seen as passive data repositories with storage sizes ranging between 96 and 8192 bytes
  - Can be read
  - In some cases even written
- Currently NFC-enabled devices like smartphone or tablet PC

Experiments

- Laboratory study embedding different types of RFID tags into 4 concrete batches
  - Concrete of 30Mpa characteristic compressive strength
  - Most common concrete used in structures in Spain.
  - The design mix has:
    - cement 367Kg/m3
    - sand 594 Kg/m3
    - gravel 1.221Kg/m3
    - 185 liters of water
  - Concrete strengths were a mean of 28MPa at 7 days and 36MPa at 28 days.

Experiments

- Into each concrete cylinder two 13.56 MHz passive RFID tags were introduced at different depths –2cm and 3cm – from the concrete surface
- Response of RFID tags was measured by communicating with tags at different stages of the concrete curation

Communication with NFC Tags

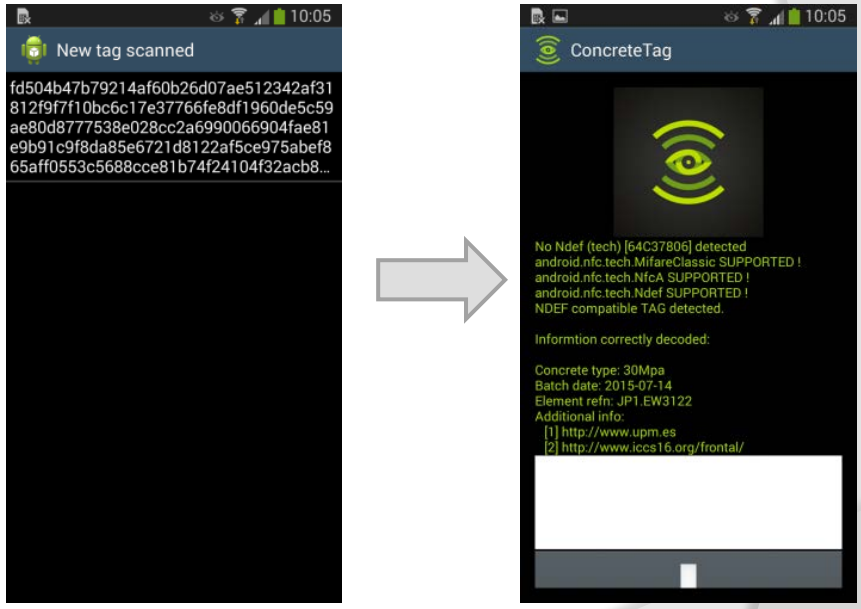
- One of the main challenges when using RFID technology is data security and privacy
- Currently there is no international standard for data storage and transmission
  - Different RFID and NFC vendors offer mutually incompatible proprietary features such as communication protocols, encoding and cypher
- An application has been developed using a custom read/writing protocol based in NFC
  - including a security encryption

Communication with NFC Tags

- Using Android application different readings were performed at different epochs in concrete curation
  - 1, 5, 10, 20, 45, 60 and 90 days after concrete mixing
- Successfully communication with all embedded tags
- This communication includes reading and writing RFID tags using both RFID readers from computers, and also using NFC communication from mobile device

Communication with NFC Tags

- Each tag includes basic information about the piece:
  - (i) concrete type and strength
  - (ii) batch number
  - (iii) batch date
  - (iv) element reference number



Information within NFC Tags

- Industry Foundation Classes (IFC) data model
- Instances of precast pieces including cement type, sand, steel, geometry, weight
- Size for storing information is very limited
  - Part of storage is used for security certificates

XML sample

```
<?xml version="1.0"?>
<!DOCTYPE rdf:RDF [
    <!ENTITY owl "http://www.w3.org/2002/07/owl#" >
    <!ENTITY genvo "http://www.gib.fi.upm.es/genvo#" >
    <!ENTITY xsd "http://www.w3.org/2001/XMLSchema#" >
    <!ENTITY rdfs "http://www.w3.org/2000/01/rdf-schema#" >
    <!ENTITY rdf "http://www.w3.org/1999/02/22-rdf-syntax-ns#" >
]>
<rdf:RDF xmlns="http://www.w3.org/2002/07/owl#"
     xml:base="http://www.w3.org/2002/07/owl"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     xmlns:genvo="http://www.gib.fi.upm.es/genvo#"
     xmlns:owl="http://www.w3.org/2002/07/owl#"
     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
    <Ontology rdf:about="http://www.gib.fi.upm.es/genvo"/>
```

XML sample

```
<!--
   ///////////////////////////////////////////////////////////////////////////////
   //
   // Object Properties
   //
   ///////////////////////////////////////////////////////////////////////////////
    -->
   <!-- http://www.gib.fi.upm.es/genvo#defines -->
   <ObjectProperty rdf:about="&genvo;defines">
      <rdfs:subPropertyOf rdf:resource="&genvo;relational_property"/>
   </ObjectProperty>
   <!-- http://www.gib.fi.upm.es/genvo#modifier_property -->
   <ObjectProperty rdf:about="&genvo;modifier_property">
      <rdf:type rdf:resource="&owl;FunctionalProperty"/>
   </ObjectProperty>
</rdf:RDF>
```

Small XML not suitable
1.401 Kilobytes

Conclusions: achieved goals

- Availability of achieving long term electronic labelling by using RFID technology embedded in the concrete piece
- Using RFID tags within concrete pieces provides a durable, robust and reliable way of labeling during transportation and building stages of BIM pieces
- This labeling could ease building management by providing information directly from concrete pieces

Conclusions: Initial product

- A prototype Android application has been developed offering a simple and affordable interface for reading information through NFC technology
  - Able to read encrypted contents written in NFC tags and show decrypted information from concrete

Conclusions

- Successful communication with all embedded RFID tags into essay concrete batches
  - During different moments in the lifetime of the batches
- Information stored in the RFID component is limited by the tag capacity
  - Data linkage techniques can be used for pointing to detailed information using URLs

Future Work

- There is still room for improvement
  - RFID added value with sensors => living data in instances
  - Web Platform managing data obtained from mobile application linking inteoperable/broker with BIM
    - Industry Foundation Classes
  - Tag encryption and locking
  - Effects of chlorides and carbonation

Thank you !

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