

Implementation Protocol Utilising Radio Frequency Identification (RFID) and Biometric Identifiers; In the Context of Irish Bovine Traceability

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1. Introduction

1.1 Irish cattle traceability

The Irish Department of Agriculture, Fisheries and Food (DAFF) is the authority responsible for the implementation of EC 1760/2000, which outlines the requirements for the identification and registration of bovine animals. Since the mid 1990's computerised databases have been established specifically the Calf Birth Registration System and the Cattle Movement Monitoring System (CMMS) (DAFF, 2003). The CMMS was initiated to record all information on births, movement, deaths and disposals. Computer equipment linked to the central database was installed in abattoirs and export points to electronically record all animal movements to and/or from these premises. As the CMMS relies on paper records for notification of certain events such as, births (herd keepers have seven days to notify the Calf Birth Registration System) and on-farm deaths, it cannot be said that it is totally accurate at a given point in time. The figures from the official CMMS statistics reports published each year reflect this, out of which a summary of the herd population statistics for recent years can be seen in Table 1. The start of January figures are calculated by taking the population figure at the end of December for the year in question from the CMMS database and adding all the disposals (cattle slaughtered, exported and on-farm deaths) and subtracting all the births and imports that have been recorded on the CMMS for that year.

	Year	Pop.	Year	Pop.	Year	Pop.	Year	Pop.
End of Dec	2003	6,589,974	2004	6,501,788	2005	6,532,706	2006	6,321,823
Start of Jan	2004	6,502,322	2005	6,489,962	2006	6,464,038	2007	6,303,313
Surplus		87,652		11,826		68,668		18,510

Table 1. CMMS cattle population data 2007 - 2003 (DAFF, 2004, DAFF, 2005, DAFF, 2006a, DAFF, 2007, DAFF, 2008)

At the current point in time barcodes are the data carriers used on cattle eartags in Ireland. However, there are issues with the readability of barcodes, of which Stanford et al., (2001) list a number of factors that can affect the read rates of eartag barcodes:

- quality of readers/scanners (ruggedness);
- direct sunlight;
- environmental conditions (i.e. cold, rain, etc);
- dirt/manure contamination of tags;
- quality and size of barcodes; and,
- the contrast between barcode and the colour of the tag.

As a result of this the identity of bovines is not being exclusively electronically recorded at the point of slaughter as called for by EC/1760/2000. Shanahan et al., (2007) have developed a genetic algorithm that can recover up to 42.4 % of damaged GS1 Code128C barcode contents, however, this still requires the barcode check digit to be recovered.

1.2 Radio frequency identification (RFID)

RFID tags are becoming more ubiquitous in the modern day world; they are finding more applications daily. Some current uses are theft prevention, automatic toll collection, building access control and animal identification (Landt, 2005). A basic RFID system is comprised of tags and readers. RFID tags each programmed with a unique identification number, may be passive (no on-board power source), semi-active (containing on-board source, for on-board power consumption) or active tags (containing on-board batteries, used for all power requirements including reader communication). The readers are comprised of an antenna, transceiver, decoder (Domdouzis et al., 2007). The reader emits a radio signal via its antenna and if there is a tag in the activation field that responds with an adequate signal strength, it picks up the signal from the RFID tag, translates the data into binary format and forwards data to a connected computer or displays it (Domdouzis et al., 2007). RFID systems operate at one of a number of different frequencies which are shown in Table 2.

	Low Frequency (LF)	High Frequency (HF)	Ultra High Frequency (UHF)	Microwave
Frequency Range	120-139 kHz	13.56 MHz	860-960 MHz	2.45 GHz
Read Range	< 0.5 m	~ 1 m	~ 4 - 5 m	~ 10 m
Main Application	Animal identification	Smart cards	Item level tracking	Electronic car toll collection

Table 2. RFID standard frequencies and related applications (The Institution of Engineering and Technology, 2005)

The ISO (International Standards Organisation) have published standards, ISO 11784 / 11785, for the use of RFID tags for animal identification (Kampers et al., 1999). These standards relate to 64 bit passive RFID tags operating at a low frequency (LF) range of 124 kHz - 139 kHz. Low frequency RFID tags are suitable for use in animal identification as electromagnetic waves at this frequency of operation suffer lower levels of attenuation due to environmental factors such as water, however, there is a reduction in read range compared to RFID tags that operate at a higher frequencies (Gandino et al., 2007). The code structure for ISO 11784 can be seen in Table 3. At the moment the ISO is working on a new

standard, the ISO 14223, for use in animal identification which as of yet has not been published. In the new standard the ISO will define the code structure for advanced RFID tags, which can have a larger memory than 64 bits, such a tag will be identified by a binary flag '1' at its 16th bit to indicate it has a larger memory capacity. The advanced tags will have features such as: authentication (for greater security), multipage memory (pages will have predefined number of bits, and can be read-only, write once/read many times or random access memory) and on-board sensors which enables them to record environmental conditions (Jansen & Eradus, 1999).

Bit no.	Information	Numeric content	Numeric length	Values
1	Animal	0 – 1	1	1 (animal flag)
2-15	Reserved field	00,000 – 16,383	5	00000
16	Additional data block flag	0 – 1	1	0 (no additional data)
17-26	Country code (ISO 3166)	0000 – 999	3	372 (Ireland)
27-64	Individual identification code	000,000,000,000 – 274,877,906,943	12	000,000,000,000 – 274,877,906,943

Table 3. ISO 11784, 64 bit code structure for animal identification (Kampers et al., 1999)

1.3 EPCglobal network

The EPCglobal Network originally developed at the Auto-ID centre in Massachusetts Institute Technology, now has its standards maintained by EPCglobal Inc. (Min Kyu et al., 2006). The EPCglobal Inc., seeks to facilitate the realisation of an “internet of things” by producing standards for the transfer of data relating to items tagged with RFIDs. Central to the strategy is the use of an Electronic Product Code (EPC), which is a globally unique number, carried by an RFID tag that can be used to identify the product to which it is attached at item or pallet level. The use of the EPCglobal Network will help reduce potential discrepancies inherent in the current CMMS database as exemplified by the figures in Table 1. GS1 (Global Standards Agency, formed by a merger of Uniform Code Council (UCC) and European Article Numbering (EAN) International) is the parent company of EPCglobal Inc. and allows the use of GS1 codes such as SGTIN (serialised global trade item number) and SGLN (serialised global location number, used to identify individual trade units which would be a bovine in this instance) in the formation of EPCs (EPCglobal Inc., 2007a).

The EPCglobal Network aims to share product traceability data between different partners in the supply chain, through the EPCIS (electronic product code information service). The EPCIS encompasses both interfaces for data exchange and specifications of the data itself, which may be either: *static data*, which will not change over the life of the object; or *transactional data*, which will change as the object travels through the supply chain (EPCglobal Inc., 2007a).

The EPCglobal Network locates information about specific EPCs by the use of Object Name Service (ONS) that is analogous to the Internet Domain Name Service (DNS) (Min Kyu et al., 2006). If information is required about a particular EPC (for instance, an SGTIN), the enquirer will contact the root ONS controlled by EPCglobal which will use the company

prefix, also known as the EPC Manager Number, to point towards the local ONS and the related EPC, which in turn will provide a pointer to the EPCIS service in question (EPCglobal Inc., 2007a). A graphical representation of this process can be seen in Figure 1. A manager number is assigned to an organisation who subscribes to the EPCglobal Network by the issuing agency (GS1); in this case it will be used to identify DAFF as the manager. The manager number gives an organisation the right to use the EPC namespace based on the GS1 family of codes; also it ensures the uniqueness of the serial number that follows.

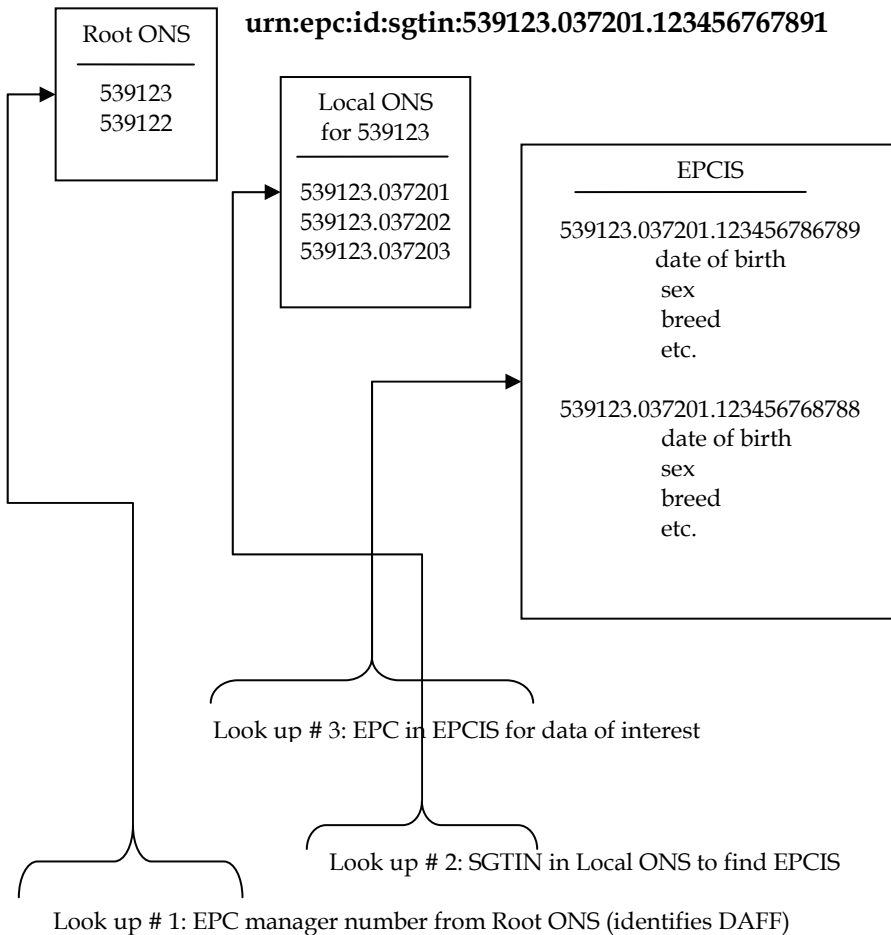


Fig. 1. Illustration of an EPCIS query for the SGTIN 539123.37201.12346786789 (adapted from EPCglobal Inc., 2007a)

1.4 Biometric identification

Biometrics has a great potential as a tool for identification or the verification of identity of individual animals. A physiological characteristic may be used as a biometric identifier as long as it satisfies the following (Jain et al., 2004):

- universality – the characteristic must be common to the population;
- distinctiveness – there should be sufficient difference in the characteristic among the population;
- permanence – the characteristic should not vary over time; and,
- collectability – the characteristic must be able to be measured quantitatively.

Various methods may be applied such as DNA testing (Stanford et al., 2001), muzzle prints (Barry et al., 2007) or retinal imaging (Barcos, 2001; Barry et al., 2007; Stanford et al., 2001). With regards to cattle, DNA testing has been developed into commercial applications in Ireland such as the identiGEN Ltd. system (Cunningham & Meghen, 2001). However, the disadvantage of using DNA testing is that it cannot provide instant results and is costly for testing large numbers of animals (Stanford et al., 2001), Dalvit et al., (2001) also points out that this technique will not be able to differentiate between monozygotic twins and cloned animals. Muzzle printing has been examined by Barry et al., (2007), who noted difficulties in obtaining satisfactory prints using ink, they also experimented with taking gray-level digital images but concluded that further study was necessary to be carried out on the automation of image capture and an increase of the testing population before this method of biometric identification could be recommended as a feasible method of identity verification.

Retinal imaging of cattle has been examined by Allen et al., (2008) where they reported 100 % accuracy in the matching of retinal images from their tests, with 98.3 % matched using a computer algorithm and the remaining 1.7 % visually. They completed their trials using the Optibrand™ system, which comprises of a handheld device for the capture of retinal images. Retinal images for both eyes of the cow can be captured in under two minutes with the use of a cattle crush to restrain the animal (Allen et al., 2008). Gonzales-Barron et al., (2008) carried out a similar study with the Optibrand™ system on sheep, where they proposed using retinal images from both eyes to confirm identification and found that this method provided a matching rate of 100 %. Retinal imaging, although a highly accurate method of biometric identification, has some drawbacks: operators require training periods; animals have to be restrained; and if imaging is required to be done outside, a shade will have to be provided to reduce the narrowing of the animal's iris which can affect the quality of the image obtained (Allen et al., 2008; Gonzales-Barron et al., 2008).

The main advantage of retinal imaging over other types of biometric identification is the near real-time results; images obtained for the Optireader™ can be compared visually to a printout or an online database beside the animal. Work completed by Rusk et al., (2006) summarised in Table 4, demonstrates the reliability of visual matching of retinal scans. The subjects who completed the visual matching had not viewed retinal images before, implying no need for previous experience. In Table 4 the final column shows the total verified after being sent to the Optibrand technicians for matching using electronic methods. In the same study, Rusk et al., (2006), had the test subjects view 156 ovine retinal images, 100 % of which were visually matched.

As the anticipated number of images and their matching is an enormous task, the BioTrack database will constitute an essential component of the traceability infrastructure. This data will hold information on the origin and identity of cattle and will be used in conjunction with the CMMS database for the verification of cattle identity but will operate independently of the CMMS database. In cases where the existing contents of a barcode are unrecoverable, the matching of retinal scans would be sufficient for the electronic identity verification of the animal. However, when phased in the use of RFID tags as data carriers would improve this situation as RFID tags can operate with a high level of accuracy in

adverse environmental conditions more so than the incumbent barcode (Huber et al., 2007). In conjunction with the BioTrack database the use of RFID will improve the electronic recording of animal identity at the point of slaughter.

Animals enrolled	Re-imaged	Visual match %	Verified overall %
70	45	100	100
88	66	100	100
163	84	88.8	91.7
78	57	91.2	96.4
92	65	95.4	98.5
	317	95.08	97.32

Table 4. Visual matching of retinal images adapted from Rusk et al., (2006)

This study will detail two alternative code structures for Irish bovine identification that can be accommodated on ISO 11784 compliant tags and can be integrated into the EPCglobal Network by the use of a middleware, thus allowing DAFF to become the custodian of real-time traceability data including identity verification through the use of biometric identifiers. This study will also suggest an implementation strategy for a web based BioTrack database, for cattle retinal scans.

2. Irish cattle identification: eartag number, ISO 11784, EPC and compatibility

The identification number used in Ireland for cattle is a 12-digit numeric code encoded in GS1 Code128C barcode. In addition, the eartag also displays a 2 letter country code, which is not encoded on the eartag barcode. The numeric code is comprised of; a two digit region code, representing one of 29 separate regions in Ireland each controlled by a District Veterinary Office (DVO); a 5 digit herd code, each representing a herd keeper; a check digit, the algorithm of which is controlled by DAFF and is not in the public domain; and finally, a 4 digit animal identifier. An example of an eartag is shown in Figure 2.

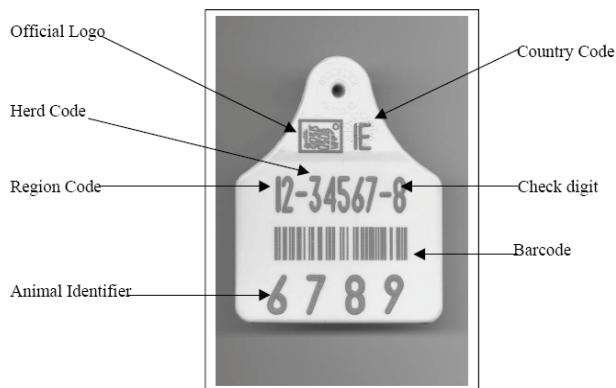


Fig. 2. An example of an Irish cattle eartag issued by DAFF (DAFF, 2006b)

In its current format, the identification number used in Ireland for cattle cannot be represented on either an ISO 11784 compliant RFID tag or as an EPC, due to the fact that the

twelve digit serial number field in both does not have a wide enough range to accommodate the identification number. From the point of view of the integrity of the traceability system, it is necessary to have a single constant identification number that can be used on visual eartags, the electronic RFID tags and as an EPC. It is a legal requirement, that both eartags shall have the same unique identification code which can identify the individual animal and the holding where it was born (EC, 2000). In this section two alternative code structures are proposed that can be expressed as an EPC and comply with ISO 11784 and at the same time satisfying the requirements of EC 1760/2000.

EPCglobal Inc. have published standards on the data content of Class-1 Generation-2 passive UHF RFID tags that operate at a frequency range of 860 - 960 MHz (EPCglobal Inc., 2008). LF RFID tags are used for electronic identification of animals, with ISO 11784 being the standard. As stated earlier UHF RFID tags are not generally considered suitable for use in animal identification, a study by Sundermann and Pugh, (2008) indicated that UHF tags may have some potential but they recommended further study with larger test numbers. Tables 5 and 6 detail two alternative proposed code structures for an EPC based upon the SGTIN code structure. It is important to note that the EPC serial number field is of the same length as the ISO 11784 serial number field, both accommodating 12 digits.

There are three important fields in the SGTIN code structure. The first field is the manager number assigned to DAFF to identify them as custodians of the EPC in question. The item reference is the second important field and is used by the EPC manager (DAFF in this case) to further classify the EPC into different product classes. In Table 5 the number '037201' is suggested as the item reference, where the leading '0' is used to expand the field to six digits; the '372' is the ISO 3166 Country Code for Ireland; and the '01' refers to a bovine. This field can be used to identify other animals that will require tracing, for example '02' may be assigned to identify sheep, '03' for goats etc. The final field is the serial number field which is a 38 bit field that can be used to represent a 12 digit number with a maximum value of 274,877,906,943. This field will hold the identification number of the individual bovine; however, it is not large enough to contain the eartag identification number in its current format. As stated earlier there are 29 separate regions in Ireland, these regions are encoded by using the set of numbers from 11 to 39 inclusive. The first two digits of the cattle identification number are comprised of the region code. The cattle identification number could not be accommodated by either ISO 11784 or EPC in its current format, because the highest representation available to the first two digits in the serial number field is '27'. A proposed solution, shown in Table 5, is to omit the check digit from the ISO 11784 compliant tag and the EPC, thereby decreasing the length of the cattle identification number to eleven digits thus allowing adequate space to accommodate the identification number in both standards. As there is an inbuilt error check mechanism that exists in electronic tags (Kampers et al., 1999), the omission of the check digit from the eartag number will not seriously affect its integrity.

An alternative structure for a SGTIN is presented in Table 6. In this structure the region code is omitted completely. As of the end of 2007, there were 112,931 separate herds in Ireland (DAFF, 2008). The current identification number carried on eartags has a five digit herd code, this is not sufficient on its own to uniquely identify the holding of origin, (as required by EC/1760/2000) but it is used in conjunction with the region code (2 digits), meaning in total seven digits are used to uniquely identify the holding of origin. If the herd code was increased to six digits, this would provide adequate namespace to uniquely identify the holding of origin, without the need for a region code. The numeric representation of which

could be as high as 274,877; more than twice the number of herds currently in Ireland. This would also enable the animal identifier to be increased to five digits utilising the extra digit freed by the omission of the region code. An expansion to five digits for the animal identifier may prove necessary to ensure adequate namespace so that the EPC is a globally unique number over the lifespan of a bovine, which is typically 20 – 25 years (Kernan, GS1 Ireland, personal communication). In this proposed structure the check digit could be retained.

Field description	Bits	Allowed Digits	Values	Meaning
Header	8	n/a	0011 0000	Identifies the following code as a SGTIN.
Filter value	3	1	010	Standard trade item grouping.
Partition	3	1	6	Determines the length of next three fields.
Company prefix	20	6	539123	DAFF assigned prefix from GS1.
Indicator digit	4	1	0	Default.
Item Reference	20	6	037201	International region code '372' ISO-3166 & Bovine identifier '01'.
Serial number	38	12	0 – 274,877,906,943	Region code (2) & Herd code (5) & Individual animal identifier (4).

Table 5. Proposed EPC SGTIN code structure for Irish bovine identification

For both examples given above the ISO 11784 encoding will be the same as the serial number field of the EPC, this serial number would then be used on the visual eartag to uniquely identify the animal and satisfy the requirements of EC/1760/2000.

Field description	Bits	Allowed Digits	Values	Meaning
Header	8	n/a	0011 0000	Identifies the following code as a SGTIN.
Filter value	3	1	010	Standard trade item grouping.
Partition	3	1	6	Determines the length of next three fields.
Company prefix	20	6	539123	DAFF assigned prefix from GS1.
Indicator digit	4	1	0	Default.
Item Reference	20	6	037201	International region code '372' ISO-3166 & Bovine identifier '01'.
Serial number	38	12	0 – 274,877,906,943	Herd code (6) & Check digit (1) & Individual animal identifier (5).

Table 6. Alternative proposed EPC SGTIN code structure for Irish bovine identification

Within the GS1 encoding structure a GLN (global location number) is the identification key for physical locations. A GLN is a 13 digit number, consisting of a company prefix, location reference and a check digit (EPCglobal Inc., 2008). Within the Irish beef traceability context a GLN will be used to identify individual holdings, for this purpose it would be desirable to maintain the 6 digit herd code as the location reference as proposed in the code structure outlined in Table 6. The code structure of a SGLN (serialised global location number) is similar to the SGTIN, the main differences being the serial number field will not be utilised and the decoding of the SGLN involves calculating a check digit that is a component of the GLN. Table 7 shows the code structure for a 96 - bit SGLN, based on the 6 digit herd code as proposed in Table 6 for the SGTIN.

In order to extract a GLN from a SGLN it is necessary to calculate the check digit, this is achieved by concatenating the company prefix and the location reference into a string represented by $(d_1 d_2 \dots d_{12})$. The check digit (d_{13}) is calculated using the formula in Eqn. 1 (EPCglobal Inc, 2008).

$$d_{13} = (-3(d_2 + d_4 + d_6 + d_8 + d_{10} + d_{12}) - (d_1 + d_3 + d_5 + d_7 + d_9 + d_{11})) \bmod 10 \quad (1)$$

Once calculated the check digit, d_{13} , is concatenated to the company prefix and the location reference to give the GLN, represented by $(d_1 d_2 \dots d_{13})$. For the SGLN in Table 7 the GLN would be displayed as the decimal 5391231586520.

Field description	Bits	Allowed Digits	Values	Meaning
Header	8	n/a	0011 0010	Identifies SGLN.
Filter value	3	1	001	Physical location
Partition	3	1	6	Determines the length of next two fields.
Company prefix	20	6	539123	DAFF assigned prefix from GS1.
Location reference	20	6	158652	6 digit Herd code
Extension component	41	15	0 - 999,999,999,999	Not applicable to this example

Table 7. Proposed EPC 96-bit SGLN code structure for Irish herd identification

Subscribers to the EPCglobal Network often have different requirements / business processes to be accommodated. To facilitate this, a middleware is often required to translate RFID data into appropriate information for specific purposes. To this end, we have developed software to translate cattle eartag numbers into the suggested ISO 11784 and EPC encodings and formulate a GLN from the company prefix and the 6 digit herd code, an example of the transformation of an identification number into EPC and ISO formats can be seen in Figure 3. The EPCglobal Network is system independent; that is, it is concerned with the transfer of information in a standard format that can be read by users no matter what internal software they are operating (EPCglobal Inc., 2007b). The manner in which the information is translated into the required standard can be defined by individual organisations through the use of middleware. The advantage to this approach is that it gives organisations the freedom to tailor the software to their specific needs. In the case of DAFF

this would mean that instead of purchasing / developing an entirely new software package from the ground up, they could employ middleware to translate the traceability information already stored in the CMMS database into EPC compliant format.

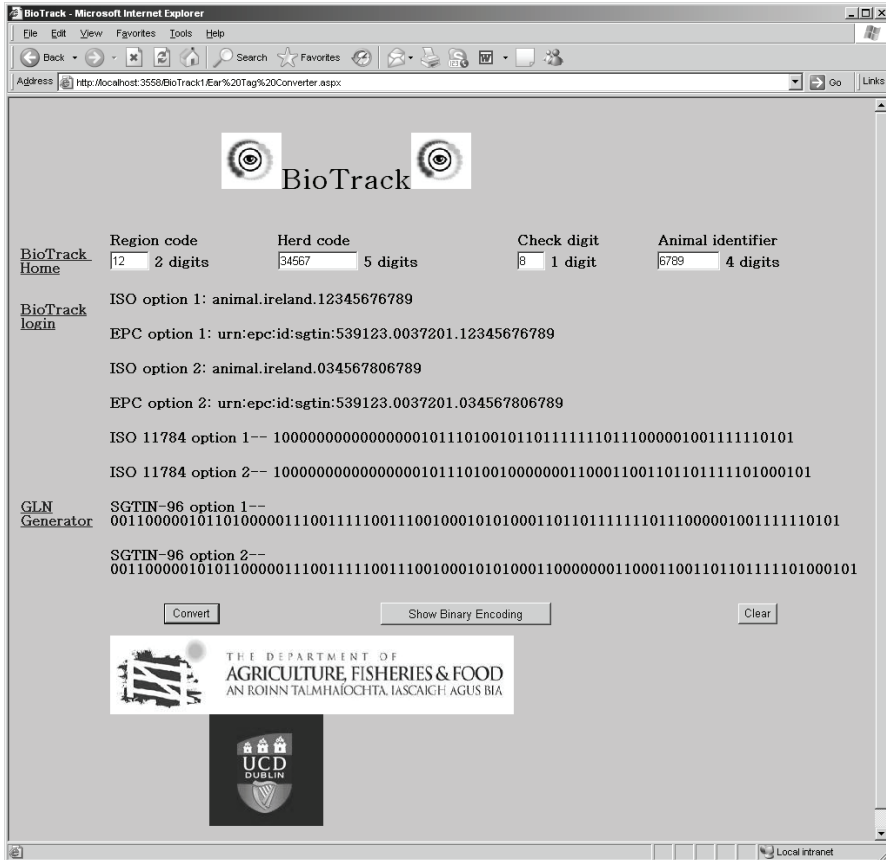


Fig. 3. Example of web based middleware for the transformation of Cattle identification number to ISO 11784 and EPC

3. A model for phased implementation of the BioTrack database

The provision of identity verification at the point of slaughter is the main aim of BioTrack - the ability to know for sure that animal A is in fact animal A, to validate all the traceability information associated with the given animal for the pre-slaughter supply chain. The contents of the BioTrack database have been outlined by Shanahan et al., 2009:

- eartag number
- retinal scan right
- retinal scan left
- eartag image
- herd details (name/address)

- date of birth
- GPS location
- scan date/time stamp
- device ID
- operator ID

An example of a record stored in the BioTrack database and the visual display in a web browser can be seen in Figure 4.

The implementation of BioTrack should be completed on a phased basis. Optireaders™ should be made available where there is an existing link to the CMMS database, namely; marts, export points and slaughtering locations. Once they are located in these areas they can be used for the capture and verification of cattle identity. Of a total of 2,519,885 cattle movements which occurred in 2007, 1,625,290 of these were carried out at marts (DAFF, 2008), this represents approximately 26 % of the national herd (this figure does not take into account animals that were sold at mart multiple times during 2007). There are a number of advantages to installing biometric capture points at marts:

- farmers can become familiar with the technology;
- there is an existing link to the CMMS database for the upload of data; and,
- large proportion of the cattle being traded at marts are being sold for fattening purposes which means that they will ultimately end up going for slaughter (where the BioTrack database can be consulted for identity verification).

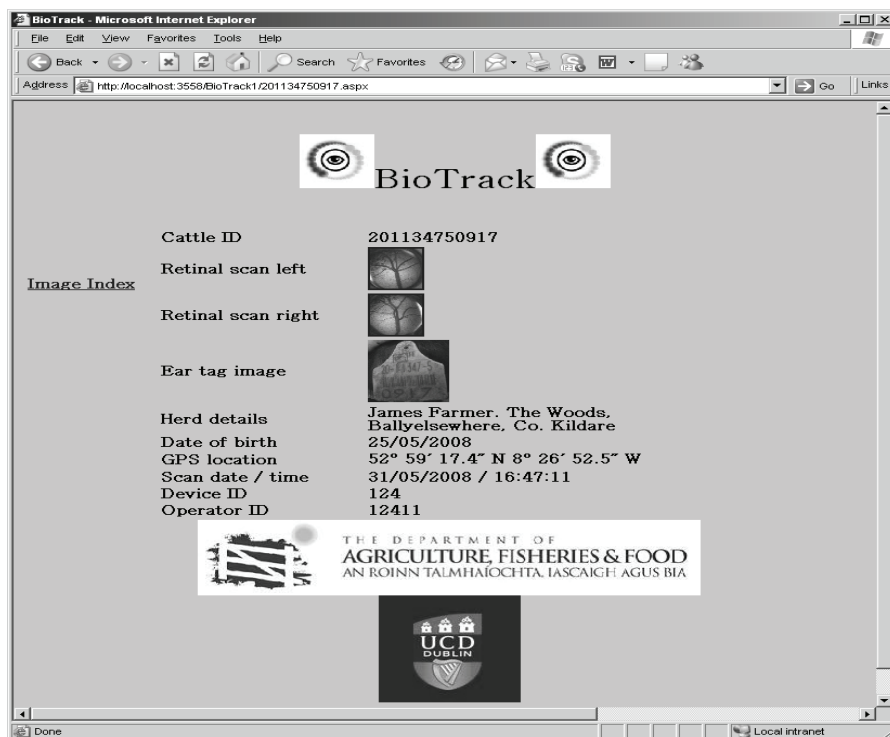


Fig. 4. Display of a BioTrack record in a web browser

Many large retailers and beef processors carryout direct trading with the herd keepers that supply their cattle, and this is an area that can be targeted for an initial capture of biometric identifiers. A total of 1,694,488 cattle were slaughtered in factories, this being 75 % of all cattle disposals in 2007 and 27 % of the national herd. On-farm deaths accounted for 12 % of disposals, the remainder of disposals were export (10 %), and local authority licensed abattoirs (3 %) (DAFF, 2008). As the statistics show if retailers and processors made it a requirement that their supplier's record a biometric identifier from their animals, the direct trading section of the supply chain would constitute a large proportion of the beef destined for the consumer's plate, and would have adopted biometric identity verification.

Aside from biometric collection at marts and animals destined for the commercial sector DAFF will have to implement a process for biometric collection of the national herd. This would be the responsibility of DVOs. Veterinary officers of the DVO currently carry out a number of farm inspections each year, the purpose of which is to ensure animal health and that housing conditions are of an adequate standard (DVO, County Dublin, personal communication). It would be possible for the veterinary officers to record the retinal images and identification numbers of all cattle on the farm during these inspections, which would also allow the DVO personnel to accumulate experience while gathering biometric identifiers. It would be unrealistic to expect that the BioTrack database could be populated with the retinal images of the 6 million plus Irish herd at once; however, efforts should be focused on a phased recording of biometrics for beef cattle as they are most likely to be destined for the consumer's plate.

Once the retinal image has been captured it will be up-loaded to the BioTrack database which will be under the control of DAFF. The BioTrack database will be linked to the EPCglobal Network through the use of the ONS, allowing stakeholders along the supply chain to query traceability and identity information. It is envisioned that there will be a flag indicating whether or not a retinal image has been captured for a specific animal, which will be displayed if a request for EPC information is received.

4. Discussion

While there are advantages to employing a traceability system based on RFID tags utilising the EPCglobal Network for the exchange of information, there are some considerations that have to be taken into account. Currently the average herd size in Ireland is 55 head, however 41 % of herds have less than 25 head of cattle (DAFF, 2008); and it may not be practical for herd keepers of this magnitude to implement RFID systems. Taking economics of scale into account it may be more advantageous to start with the 24 % of herd keepers that have more than 75 head of cattle (DAFF, 2008), it could be safely assumed that herd keepers of this size already have some farm management software to aid production and would be more comfortable with technological advancements in farming practices. Once a herd is fitted with electronic eartags there are other values that can be obtained from the system; such as automatic feed distribution, individual milk yield recording and automatic live weight gain recording (Erasmus and Jansen, 1999; Rossing, 1976). Under the current system in Ireland the cost of eartags for cattle (currently priced at € 2.15 for a single eartag and € 2.94 for pair of eartags as shown in Figure 2 (Eurotags, personal communication) is borne by the herd keeper. RFID enabled eartags are slightly more expensive - costing approximately € 3 for a single tag (Eurotags, personal communication). A survey of

American electronic tag suppliers (7 quotes) gave an average price of € 1.73 (exchange rate of 0.635 as at 09/07/2008) for ISO 11784 compliant RFID eartags (This study).

There are now mobile phones and personal digital assistants (PDAs) with in-built RFID / barcode readers on the market, making it possible for herd keepers to record the identification numbers of cattle and through a system described by Min Kyu et al., (2006), enabling communication through the EPCglobal Network via a mobile phone network which could facilitate requests for movement authorisation from the CMMS, which would streamline the process and make redundant the need to apply in writing for cattle movement authorisation.

5. Conclusion

The accurate and timely identification of cattle is a necessity if full chain traceability from farm to fork is to be achieved. With current technology such as RFID cattle tags, cattle identification numbers can be captured automatically and shared along the supply chain through the use of the EPCglobal Network, which would rely upon the traceability infrastructure already maintained by DAFF. The use of retinal images as a biometric, stored on a BioTrack database to verify identity would provide a system check that would be virtually fraud-proof. While such a system may be costly to implement it is suggested that larger herd keepers and suppliers to major retailers and processors be the first to adopt the RFID tagging and biometric capture, while marts and commercial slaughterhouses can be the first premises to install biometric identity verification systems. A system such as this would be able to identify cattle whose eartag has been tampered with; in the case of a retinal image not matching to the identification number on the eartag, it would be an indication that fraudulent activity may have occurred and such an animal should not be allowed to go to slaughter and an investigation initiated by the district veterinary officer, who is required under Irish law to be present at all cattle slaughtering. The introduction of BioTrack would provide a mechanism for source and identity verification of Irish beef products, the utilisation of the EPCglobal Network would also ensure that trading partners around the globe will have confidence in the traceability infrastructure commensurate with the high standards of production employed in Ireland thus adding value to the beef sector.

6. References

- Allen, A.; Golden, B.; Taylor, M.; Patterson, D.; Henriksen, D. & Skuce, R., (2008). Valuation of retinal imaging technology for the biometric identification of bovine animals in Northern Ireland. *Livestock Science*, 116, 1-3, pp. 42-52, ISSN 1871-1413
- Barcos, L. O., (2001). Recent developments in animal identification and the traceability of animal products in international trade. *Rev. sci. tech. Off. int. Epiz.*, 20, 2, pp. 640-651
- Barry, B.; Gonzales-Barron, U. A.; McDonnell, K.; Butler, F. & Ward, S., (2007) Using muzzle pattern recognition as a biometric approach for cattle identification. *Transactions of the ASABE*, 50, 3, pp. 1073-1080, ISSN 0001-2351
- Cunningham, E. P. & Meghen, C. M., (2001) Biological Identification systems: genetic markers. *Rev. sci. tech. Off. int. Epiz.*, 20, 2, pp. 491-499
- Dalvit, C.; De Marchi, M. & Cassandro, M., (2007) Genetic traceability of livestock products: A review. *Meat Science*, 77, 4, pp. 437-449, ISSN 0309-1740

- Department of Agriculture, Fisheries and Food (DAFF), Ireland, (2003) *CMMS Statistics Report 2002*. Available online at: <http://www.agriculture.gov.ie/media/migration/animalhealthwelfare/animalidentification/cattlemovementmonitoringsystem/cmmsstatsrept.pdf> Accessed on 15/07/2008.
- Department of Agriculture, Fisheries and Food (DAFF), Ireland, (2004) *CMMS Statistics Report 2003*. Available online at: http://www.agriculture.gov.ie/media/migration/animalhealthwelfare/animalidentification/cattlemovementmonitoringsystem/cmms_stats.pdf Accessed on 15/06/2008.
- Department of Agriculture, Fisheries and Food (DAFF), Ireland, (2005) *CMMS Statistics Report 2004*. Available online at: <http://www.agriculture.gov.ie/media/migration/animalhealthwelfare/animalidentification/cattlemovementmonitoringsystem/CMMSStatsreport2004.pdf> Accessed on 15/06/2008.
- Department of Agriculture, Fisheries and Food (DAFF), Ireland, (2006a) *CMMS Statistics Report 2005*. Available online at: <http://www.agriculture.gov.ie/media/migration/animalhealthwelfare/animalidentification/cattlemovementmonitoringsystem/CMMSStatsreport2005.pdf> Accessed on 15/06/2008.
- Department of Agriculture, Fisheries and Food (DAFF), Ireland, (2006b) *Competent authority, model of passport, eartags and holding register*. Available online at: <http://www.agriculture.gov.ie/media/migration/animalhealthwelfare/animalidentification/cattlemovementmonitoringsystem/ireland.pdf> Accessed on 01/09/06.
- Department of Agriculture, Fisheries and Food (DAFF), Ireland, (2007) *CMMS Statistics Report 2006*. Available online at: <http://www.agriculture.gov.ie/media/migration/animalhealthwelfare/animalidentification/cattlemovementmonitoringsystem/StatisticsReportInside2006.pdf> Accessed on 07/02/2008.
- Department of Agriculture, Fisheries and Food (DAFF), Ireland, (2008) *CMMS Statistics Report 2007*. Available online at: <http://www.agriculture.gov.ie/media/migration/animalhealthwelfare/animalidentification/cattlemovementmonitoringsystem/CMMSreport2007.pdf> Accessed on 07/07/2008
- District Veterinary Office, (2008), Dublin, Personal communication.
- Domdouzis, K.; Kumar, B. & Anumba, C., (2007) Radio-Frequency Identification (RFID) applications: A brief introduction. *Advanced Engineering Informatics*, 21, 4, pp. 350-355, ISSN 1474-0346
- EPCglobal Inc., (2007a) *EPC Information Services (EPCIS) Version 1.0.1*. Available online at: http://www.epcglobalinc.org/standards/epcis/epcis_1_0_1-standard-20070921.pdf Accessed on 25/07/2008
- EPCglobal Inc., (2007b) *The EPCglobal Architecture Framework*. Available online at: http://www.epcglobalinc.org/standards/architecture/architecture_1_2-framework-20070910.pdf Accessed on 15/07/2008
- EPCglobal Inc., (2008) *EPCglobal tag data standards version 1.4*. Available online at: http://www.epcglobalinc.org/standards/tds/tds_1_4-standard-20080611.pdf Accessed on 03/07/2008
- European Commission, (2000) *Regulation (EC) No 1760/2000 of the European Parliament and of the Council of 17 July 2000 establishing a system for the identification and registration of bovine animals and regarding the labelling of beef and beef products and repealing Council Regulation (EC) No 820/97*. Available online at: <http://eur-lex.europa.eu>

- /LexUriServ/LexUriServ.do?uri=OJ:L:2000:204:0001:0010:EN:PDF Accessed on 15/01/2008
- Eurotags (2008), Mullinahone Co-op, Ireland, Personal communication.
- Gandino, F.; Montrucchio, B.; Rebaudengo, M. & Sanchez, E. R., (2007) Analysis of an RFID-based Information System for Tracking and Tracing in an Agri-Food chain. *Proceedings of 2007 1st Annual RFID Eurasia*, pp. 1-6, ISBN 978-975-01566-0-1, Istanbul, Sept. 2007
- Gonzales-Barron, U.; Corkery, G.; Barry, B.; Butler, F.; McDonnell, K. & Ward, S., (2008) Assessment of retinal recognition technology as a biometric method for sheep identification. *Computers and Electronics in Agriculture*, 60, 2, pp. 156-166, ISSN 0168-1699
- Huber, N.; Michael, K. & McCathie, L., (2007) Barriers to RFID Adoption in the Supply Chain. *Proceedings of 2007 1st Annual RFID Eurasia*, pp. 1-6, ISBN 978-975-01566-0-1, Istanbul, Sept. 2007
- Jain, A. K.; Ross, A. & Prabhakar, S., (2004) An introduction to biometric recognition. *Circuits and Systems for Video Technology, IEEE Transactions on*, 14, 1, pp. 4-20, ISSN 1051-8215
- Jansen, M. B. & Eradus, W., (1999) Future developments on devices for animal radiofrequency identification. *Computers and Electronics in Agriculture*, 24, 1-2, pp. 109-117, ISSN 0168-1699
- Kampers, F. W. H.; Rossing, W. & Eradus, W. J., (1999) The ISO standard for radiofrequency identification of animals. *Computers and Electronics in Agriculture*, 24, 1-2, pp. 27-43, ISSN 0168-1699
- Kernan, B., (2008), GS1 Ireland, Personal communication.
- Landt, J., (2005) The history of RFID. *Potentials, IEEE*, 24, 4, pp. 8-11, ISSN 0278-6648
- Min Kyu, H.; Il Woo, P.; Byung Hee, L. & Jin Pyo, H., (2006) A Framework for Seamless Information Retrieval between an EPC Network and a Mobile RFID Network. *Proceedings of Computer and Information Technology, 2006. The Sixth IEEE International Conference on*, pp. 98-98, ISBN 0-7695-2687-X, Seoul, Sept. 2006
- Rusk, C. P.; Blomeke, C. R.; Balschweid, M. A.; Elliott, S. J. & Baker, D., (2006) An evaluation of retinal imaging technology for 4-H beef and sheep identification. *Journal of Extension*, 44, 5, ISSN 1077-5315
- Rossing, W. (1976) Cow identification for individual feeding in or outside the milking parlour. *Proceedings of the Symposium on Animal Identification Systems and their Applications*, Wageningen, 1976
- Shanahan, C.; Kernan, B.; Ayalew, G.; McDonnell, K.; Butler, F. & Ward, S., (2009) A framework for beef traceability from farm to slaughter using global standards: an Irish perspective. *Computers and Electronics in Agriculture*, 66, 1, pp. 62-69, ISSN 0168-1699
- Shanahan, C.; Ayalew, G.; McDonnell, K.; Butler, F. & Ward, S. (2007), The use of genetic algorithms for data recovery from damaged barcodes. *Proceedings of the 37th Annual Research Conference Food, Nutrition & Consumer Sciences*, pp 100-101, ISBN 978-0-9556109-1-2, University College Cork, Sept. 2007
- Stanford, K.; Stitt, J.; Kellar, J. & McAllister, T., (2001) Traceability in cattle and small ruminants in Canada. *Rev. sci. tech. Off. int. Epiz.*, 20, 2, pp. 510-522

- Sundermann, E. & Pugh, G., (2008) The application of UHF RFID technology for animal ear tagging. The New Zealand RFID Pathfinder Group Inc. Available online at: <http://www.rfid-pathfinder.org.nz/images/pdf/report-uhf-animal-tag-trials-july08.pdf>
Accessed on 10/08/2008
- The Institution of Engineering and Technology, (2005) Radio Frequency Identification device technology, a factfile provided by the Institution of Engineering and Technology. Available online at: <http://www.theiet.org/factfiles/it/rfid.cfm?type=pdf> Accessed on 08/04/2008