RFID: Applications, Operation, Numbering and Lookups

Mobile and Ubiquitous Computing

George Roussos
g.roussos@bbk.ac.uk

Overview

- RFID applications
- RFID principle of operation
- Types of tags
- Addressing
- Lookups

Identification Friend or Foe

- Introduced during WWII to distinguish between own and enemy aircraft
- Uses the Radar system
- In common use today for air traffic management
- Employs the secondary surveillance radar
- Air traffic management uses Mode 3/A or S
- Uses a lot of power

Automated Toll Collection

- Automated collection of motorway toll fees
- Battery powered device on the vehicle
- Interrogator installed at the toll portal
- Credit stored in the tag and fees deducted at every passage

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Tag people

- Verichip RFID tag FDA approved for use with humans
- Many applications claimed:
  - Medical, medication, surgery
  - Kidnap victims
  - Nightlife
  - Track offenders (150k people currently tagged in the UK)
  - Identification
- Highly hackable (more on this at the end)

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Retail

- Consumer applications: smart self, smart shopping cart, inventory tracking
- Large scale trials (Metro Supermarket, Germany)
- Actual implementations (Mitsukoshi Department Stores in Japan)
- Makes sense for high-value items only
- Passive (no battery) tags should cost less than 5 cents

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Pharmaceuticals

- Anti-counterfeiting a priority
- Additional applications
  - correct medication
  - inventory management
  - recall
- Issues related to effects of radiation on drugs

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RFID Basics

- AC oscillation at the end-points of an antenna creates magnetic and electric fields
- RFID uses these fields to transmit energy and for communication
- Depending on which field is used and how the transmitted energy is used we get different types of RFID systems

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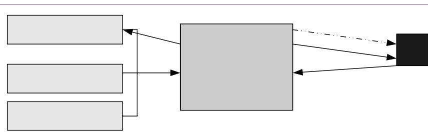
Sequence of events



1. reader configured with operational parameters
2. reader creates field that powers up the tag
3. reader initiates communication
4. tag responds
5. information returned to middleware/applications after possible additional processing step

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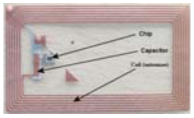
Tag components



Tag internals

Typical polymer enclosure

- Antenna (different types according to coupling method used)
- Chip (for passive tags this is a simple state machine)
- Capacitor (to store transmitted power)
- Enclosure

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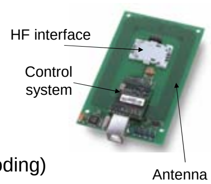
Reader components

- HF interface
  - transmitter/receiver
  - separate pathways
- Control system
  - microcontroller
  - ASIC module (crypto, signal coding)
  - network module
- Antenna
  - integrated/external
  - one or many



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Component roles

- High-frequency interface
  - generates transmission power to activate tag
  - modulates transmission/demodulates tag signal
- Control system
  - control communication with tags
    - anti-collision, data crypto, authentication
  - signal coding and decoding
  - interact with network services
- Multiple antennas are seen as one (cf. tag orientation issues later)

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Near and Far Field

- <100Mhz magnetic, inductive or near-field coupling
  - Near field means that the wavelength is several times greater than the distance between the reader and tag
  - Examples: 128 kHz and 13.56 MHz
  - Same principles as the transformer
  - Electric component is not involved
- >100Mhz capacitively or far-field coupling
  - Examples: 915MHz and 2.45 GHz
  - Same principle as the Radar
  - Magnetic field is not involved

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Active versus Passive

- Power to operate the chip
- Active tags:
  - Use battery to power up the chip
- Passive tags:
  - Power up using the coupling effect
  - Essentially the reader transmits power used by the tag
- Semi-passive tags
  - Use battery to operate the chip
  - Antenna optimized for data transmission

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Active Tags

- Advantages
  - Transmit at higher power levels
  - Longer range
  - More reliable communication
  - Can operate in challenging environments (e.g. around water)
  - Can have additional sensing capability (e.g. temperature)
  - Can initiate transmissions
- Limitations
  - Stop when their battery expires (10 years at best)
  - More expensive
  - Larger size (to accommodate the battery)

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Passive Tags

- Advantages
  - Low cost
  - No battery, so they do not expire (unless damaged)
  - Small size
  - Increasingly printable
- Limitations
  - Restricted processor, memory and communications
    - Functionality has to be offloaded to the network
    - Limited capability to protect themselves
  - Only operate in the vicinity of readers
  - Harder to operate in harsh environments

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Passive Tag Implications

- Manufacture at less than 5 cents per tag by 2010
  - not counting royalties and other IPR!
- Major interest in logistics
  - industry backing
- Massive investment by semiconductor industry
  - rapid progress on many fronts
- Key idea:
  - store only a Universally Unique Identifier in the tag
  - carry out all related processing on the network

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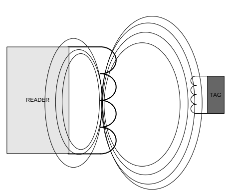
Near Field Coupling

- Employs magnetic induction
  - Same idea as the transformer
  - Coil-shaped antenna
- AC at coil->current at antenna
- Charge stored in tag capacitor
- Powers up chip
- Tag changes impendence at coil affecting current drawn by coil
- Reader decodes change via the potential variation in its resistance
- Process called load modulation



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Near Field Coupling

- Coils of reader and tag separated in space
- Coupling requires that magnetic field of reader intersects the tag coil
- This is the near field of the EM field created by AC oscillation
- Strength of field falls proportionally to $1/d^3$
  - center of reader coil to tag

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Near Field Coupling

- Size of field depends on frequency of current and limited within $2D^2/\lambda$
  - after this, the far field starts
- Examples:
  - ISO 14443 operates at 13.56MHz, NF is 3.6 meters
  - UHF 915Mhz NF is 6cm
- Larger antennas can help
- In practice most systems work in 1-30cm range

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NF Tag examples

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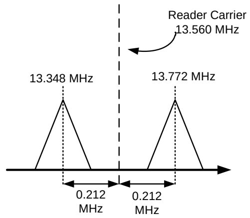
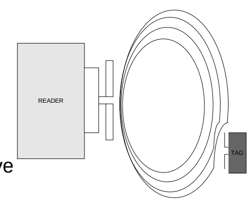
Communication with load modulation

- Voltage fluctuation at reader antenna as result of tag resistor change is tiny
  - e.g. 100V reader to 10mV signal
- Detecting this signal is a problem
- Load modulation using the subcarriers is one solution
- Load resistor of transponder switched on/off at frequency f_s then two spectral lines at $f_r \pm f_s$
- Data transmitted using this frequency



Far Field Coupling

- Antenna is a dipole
- RF backscatter rather than induction
- Backscatter: reflect back some part of reader RF signal
- Reader decodes reflections as variation in amplitude
- Reader must have very sensitive receiver:
  - energy attenuation reduces by $1/d^2$
  - so reflections $1/d^4$ of original power
  - d separation of tag and reader



Far Field Coupling

- Backscatter is the radar principle
  - electromagnetic waves are reflected by objects greater than ½ of the wavelength
- *The reflection cross section (*the signature of the object) can be modified by altering the load connected to the antenna of the tag
  - switching the tag resistor on and off creates the data stream
- Effective range of reading is typically 3-4 meters
- Reader sensitivity one microwatt
- Tags benefit from Moore's law
  - less energy needed to power up the tag

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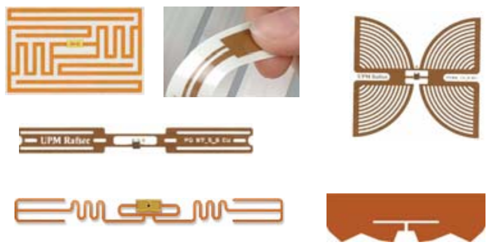
FF Tag examples



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Tag orientation effects

- Alignment of tag antenna is second most important factor in effectiveness (after distance)
- In either near field or far field systems tag must NOT be perpendicular to reader antenna
  - Tag fails to be read
- (Partial) solution to this problem:
  - Antenna design or many antennas with different alignments
  - Multiple readers (but beware of reader collisions)

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Influence of Objects and Environment

- Inductive systems
  - Unaffected by dielectric or insulator materials e.g. paper, plastics, masonry, ceramics
  - Metals weaken the field (depending how ferrous they are)
  - May also detune tags if they work at a resonant frequency
- Electric
  - Can penetrate dielectric material
  - Water molecules absorb energy
  - Metals reflect or scatter and can completely cloak tag
  - Tag on tag effect are also very strong in higher densities

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RFID Addressing

- Identifiers in RFID
- A brief history of object numbering schemes
- Object identifiers
  - EPCglobal Electronic Product Code
  - Ubiquitous ID
  - Other object numbering schemes
- Addressing objects
- The Internet of Things

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Identifiers in a Gen2 tag

- Tag identification (TID) memory bank
  - An 8-bit ISO 15963 allocation class identifier
    - For EPCglobal Tags it is 0xE2
  - A 12-bit Tag mask-designer ID
  - A 12-bit Tag model number.
  - Manufacturers can also include other information if required e.g. tag serial number
- EPC in EPC memory bank
- User memory bank may contain additional application specific IDs

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ISO 14443 IDs

- ISO 14443-A requires fixed Card Identifier (CID)
- CID uniquely related to tag chip
  - Application Family Identifier (AFI) defines separate spaces for CID
- Used by reader to address a specific card
  - Also used in groups to keep specific cards in a particular state
- In ISO 14443-B can be pseudo –random number
- Application layer identifiers are contained in user data space
  - e.g. Oyster card customer number different from ISO ID

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Addressing objects

- User-space object ID
- Generally no additional context data on tag
- Characteristics
  - Universally unique
  - Sub-domain structure
  - Registrar
  - Ownership
  - Mechanisms for mapping to metadata
- There are already some candidates!

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Numbering Systems for Objects

- Barcodes
  - many different types!
- IPv6 addressing
  - too much functionality for objects in many cases
  - requires superior processing capability and >100KB stack)
- Internet 0
  - reduced IP stacks with ISO-1800/IRDA etc link layer
  - Asymmetric, no end-to-end
- Other MAC addresses
  - embedded Zigbee, Bluetooth

UCC/EAN-128, EAN-13, EAN-8, ITF 14.

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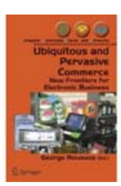
Multiple identifiers

- Objects can have multiple IDs in different schemes
  - 658.05 UBI (Dewey Classification Scheme)
  - 1846280354 (ISBN)
  - 9781846280351 (EAN)
  - 6602940 (LIBRI)



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Objects are also products

- Object manufacturer well positioned to embed ID
- Has been done before at global scale
- Major perceived business benefits in the supply chain
  - logistics, inventory, anti-counterfeiting, demand forecasting, shrinkage
- Possible consumer applications
  - smart things, smart selves, product recalls
- Major technology investment

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Barcodes and the SG1 system

- UPC created in 1973 the first American 10-digit barcode standard (uniform and then Universal product code)
- European Article Numbering introduced in 1977 extended the scheme to the needs of a global market
  - first to separate the data from the data carrier
- Two systems became interoperable in 2005 as EAN.UCC and later SG1 (One Global Standard)
- Under SG1 a variety of standardization activity including RFID within EPCglobal
  - ebXML, Global Data Synchronization Network, Global Standards Management Process, Global Product Classification

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EPC Identifiers

- A global identifier scheme is needed
  - Address allocation, coordination of address space, address semantics, resolution
- EPC is part of SG1 and so has to accommodate existing EAN and related identifiers
- Management of the scheme is via a SG1 subsidiary called EPCglobal Inc
- Protocols are developed in the Auto-ID network of research laboratories

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EPC structure

- EPC tag data standards define "pure identifiers" which are abstract object addresses
- Pure identifiers are stored following the related "physical realization" and "encoding" protocols on the tag
- *Header data* identifies the particular scheme employed in a specific EPC and thus the semantics of the digits
- Current schemes are specific to SG1 and DoD requirements and there is also a general ID

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Encoding schemes

- General Identifiers (GID-96)
- System Identifiers
  - GS1 Global Trade Item Number (GTIN) SGTIN-96 SGTIN-198
  - GS1 Serial Shipping Container Code (SSCC) SSCC-96
  - GS1 Global Location Number (GLN), SGLN-96 SGLN-195
  - GS1 Global Returnable Asset Identifier (GRAI) GRAI-96 GRAI-170
  - GS1 Global Individual Asset Identifier (GIAI) GIAI-96 GIAI-202
- DoD construct (DoD-96) cf. www.dodrfid.org

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Types of data

- Serialized Global Trade Item Number (SGTIN) -On item packaging for items where a serial number is used for the unique identification of trade items worldwide within the UCC.EAN System.
- Global Returnable Asset Identifier (GRAI)-On item packaging for items (reusable package or transport equipment).
- Global Individual Asset Identifier (GIAI) -On item packaging for items (used to uniquely identify an entity that is part of the fixed inventory of a company -GIAI can be used to identify any fixed asset of an organization).
- Serialized Shipment Container Code (SSCC)-Items shipped as either pure or mixed case, pallet, (SSCC can be used by all parties in the supply chain as a reference number to the relevant information held in computer database or file).

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Electronic Product Code

016.37000.123456.100000000			
Header	EPC Manager	Object Class	Serial Number

- *Header:* identifies the length, type, structure, version and generation of EPC
- *Manager Number:* which identifies the company or company entity (today: same as EAN)
- *Object Class:* similar to a stock keeping unit or SKU
- *Serial Number:* which is the specific instance of the Object Class being tagged

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ucode

- Not specifically related to supply chain applications
- ucode is a 128-bit number
- It is a meta-ID because it can incorporate other numbering schemes
  - provides bindings for JAN, UPC, EAN.UCC, ISBN
- It can be abbreviated for use with low-capacity carriers
  - uses context code
- Distinct domain levels, managed independently
- Registrar is Ubiquitous ID Centre
  - T-Engine Forum, University of Tokyo

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uID technologies


```
<rdf:RDF
  xmlns:rdf="http://www.w3.org/2/22/99-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:utad="urn:utad:schema:utad:base:0.0.0#"
  xmlns:pc="urn:utad:schema:pc:example:0.0.0#">
  <rdf:Description rdf:about="ucode:0123....cdef">
    <rdf:type rdf:resource="urn:utad:schema:pc:example.0.0.0#pc"/>
    <utad:version>0.0.0</utad:version>
```


- Defines specific tag classes
  - also incorporates barcodes
  - microwave, HF and UWB tags
- Defines reader device called the uID Communicator
- Defines software platform
  - Based on TRON
- Address resolution points to uTAD record with object details

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ucode structure

Length (bits)	4	16	4	variable	variable	
	ver	TLD	CC	DC	IC	Total 128 bits

- version
- Top Level Domain code
- Class Code specifies the boundary between DC and IC
- Domain Code specifies the type of IC
  - e.g. JAN, ISBN, EPC etc
- Identification Code is the actual object identifier

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RFID Directory

- The role of networked services
- Directories and Lookup
- Object Naming Service operation
- ONS and DNS

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Network RFID

- Tags have to minimize cost:
  - very limited storage, i.e. contain ID only
  - very limited computational power
- IDs by themselves are not useful
- Tradeoff: ID is the key to query the network for information
- Need:
  - directory,
  - lookup service
  - (federated) database to hold info
  - associated protocols
- Employ internet and web standards where possible
- Cost and interoperability

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EPCglobal NRFID architecture

Discovery	Object Naming Service (ONS)	Discovery of authoritative object manufacturer information
	EPC Discovery Service	Track-and trace chain information discovery (pointers to)
Storage	EPC Information Service	Store and retrieve item and class level usage information
Authentication	EPC Trusted Services	Authentication, authorization and access control

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Directory

- Map IDs to service locations
  - e.g. map product ID to web service that can be queried for its expiration date
  - does NOT include serial number
- It also maps EPC Manager IDs to EAN.UCC Company prefix
- Requirements: global directory on the internet
- Obvious candidate: Domain Name System

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DNS and X.500

- DNS maps IP numbers to names and vice versa
- In fact, it maintains general Resource Records
- Extensible using NAPTR records
- Well established API and tools
- Efficient lookups, global reach
- Decentralized: location, administration (hierarchical)
- X.500 (ITU) free search but less efficient
- White pages, yellow pages
- Update protocol, security

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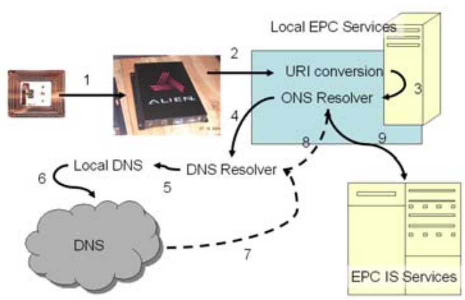
ONS lookups

- Using the usual DNS tools
- Two types of DNS resource records
  - NAPTR for EPC codes
  - TXT for company code tables
- Translating the ID into a DNS query
- Follows path to (local to authoritative) onsepc.com through DNS
- Follows path within onsepc.com from root to ID custodian local server

Query sequence



Translation

EPC 64-bit Format:
[10 000 00000000000000 00000000000000011000 0000000000000000110010000]

Step 1: Reader captures and sends to EPC event manager

10 000 00000000000000 00000000000000011000 0000000000000000110010000

Step 2: EPC EM creates URI following Tag Data Standard:

urn:epc:id:sgtin:0614141.000024.400

Step 3: To local ONS resolver:

urn:epc:id:sgtin:0614141.000024.400

Step 4: ONS resolver concerts the URI to the equivalent DNS NAPTR query

000024.0614141.sgtin.id.onsepc.com

Step 5: DNS returns result set (redirect to manager domain)

ONS Resolver

- Remove URI pre-fix

urn:epc:id:sgtin:0614141.000024.400 → 0614141.000024.400

- Remove Serial Number

0614141.000024.400 → 0614141.000024

- Invert

0614141.000024 → 000024.0614141

- Append ONS root

000024.0614141 → 000024.0614141. sgtin.id.onsepc.com

- Issue DNS query e.g.

nslookup 000024.0614141. sgtin.id.onsepc.com (set type=NAPTR)

ictx.getAttributes(epcDomainName, new String[]{"NAPTR"});
(javax.naming)

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NAPTR

- Naming Authority Pointer (NAPTR) is a type of DNS Resource Record (RFC 2915)
- Designed for Dynamic Delegation Discovery System (DDDS) applications (RFC 3401, 3401, 3403, 3404)
  - Lazy binding of strings to data
  - Supports dynamically configured delegation
- Uses regular expressions to specify a delegation point within some other namespace
- e.g. used to locate SIP users

$ORIGIN 3.8.0.0.6.9.2.3.6.1.4.4.e164.arpa.
NAPTR 10 100 "u" "E2U+sip" "!^.*$!sip:info@example.com!" .

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ONS Result Set

- NAPTR fields:
  - **Order** And **Pref** show priority of this result within the set
  - **Flags** when set to "u" means regular expression containing URI
  - **Service** designates different types of services. The format of this field is EPC+service_name where service_name can be pml, html, xmlrpc, and ws
  - **Regexp** specifies a URI for the service being described (for ONS currently it is hostname and additional path information)
  - **Replacement** specifies the replacement portion of the rewrite expression (not used in ONS)

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ONS Result Set Example

Orders	Pref	Flags	Service	Regexp	Replacement
0	0	u	EPC+pml	!^.*$!http://www.epc.dcs.bbk.ac.uk/cgi-bin/epcpml.php!	.
0	0	u	EPC+html	!^.*$!http://www.epc.dcs.bbk.ac.uk/epcpml.jsp!	.
0	0	u	EPC+xmlrpc	!^.*$!http://www.epc.dcs.bbk.ac.uk/exist/epc!	.
0	0	u	EPC+epcis	!^.*$!http://www.epc.dcs.bbk.ac.uk/epc!	.
0	0	u	EPC+ws	!^.*$!http://www.epc.dcs.bbk.ac.uk/ws/epc.wsdl!	.

Service codes:

EPC+pml: Product Markup Language document

EPC+html: Web page description

EPC+xmlrpc: XML Remote Procedure Call interface

EPC+ws: Web Service interface (WSDL)

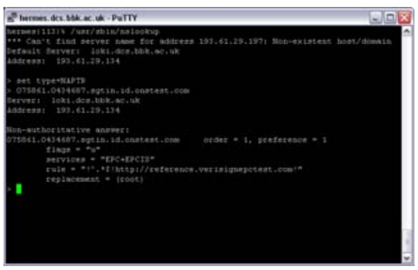
EPC+epcis: Authoritative EPC IS server

Example

Solaris 10 nslookup

Set DNS record type to NAPTR

ONS reply



Try test ONS server at epc.dcs.bbk.ac.uk