SECURE ARCHITECTURE FOR AUTOMATIC TICKETING SYSTEMS - ONLINE ENABLED

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Abstract: The paper presents a solution for endcoding/decoding access to the subway public transportation systems and the quantitative indicators about the validation process. First part of the paper is dedicated through section one to the most used 2D barcodes used in the market – QR and DataMatrix. The sample for DataMatrix is author propietary. The section two presents MMS and Digital Rights Management topics used for issuing the 2D barcodes tickets. The second part of the paper, starting with section three shows the architecture of Subway Ticketing Systems and the proposed procedure for the ticket issuing and the validation tests. The conclusions identify trends of the security topics in the public transportation systems.
Key-Words: 2D barcode, Ticketing System, DataMatrix code – ISO/IEC 16022, QR code – ISO/IEC 18004, MMS – Multimedia Message Service, M-DRM – Mobile Digital Rights Management , 2D Barcode Automatic Ticketing System – 2D BATS

1. DataMatrix – ISO/IEC 16022 and QR – Quick Response ISO/IEC 18004

Data Matrix is a 2D matrix symbology. Parts from this section are copyrighted by ISO/IEC 16022 [1]. According with [1], there are 2 types of symbologies:

- ECC 200 which uses Reed-Solomon error correction. ECC 200 is recommended for new applications.
- ECC 000 - 140 with some levels of convolutional error correction, referred to as ECC 000, ECC050, ECC 080, ECC 100 and ECC 140 respectively. ECC 000 - 140 should only be used in closed applications where a single party controls both the production and reading of the symbols and is responsible for overall system encoding/decoding procedures.

The characteristics of Data Matrix are [1]:

- Encodable character set:
  - o values 0 - 127 in accordance with ISO/IEC 646, i.e. all 128 ASCII characters (equivalent to the U.S. national version of ISO 646)
  - o Values 128 - 255 in accordance with ISO 8859-1. These are referred to as extended ASCII.
  - o Representation of data: A dark module is a binary one and a light module is a zero.

- Symbol size in modules (not including quiet zone):
  - ECC 200 is for 10 x 10 to 144 x 144 even values only
  - ECC 000 – 140 is for 9 x 9 to 49 x 49, odd values only
- Data characters per symbol (for maximum symbol size in ECC200):
  - Alphanumeric data: up to 2335 characters
  - 8-bit byte data: 1555 characters
  - Numeric data: 3116 digits.
- Selectable error correction:
  - ECC 200: Reed-Solomon error correction.
  - ECC 000 - 140: Four levels of convolutional error correction, plus the option to apply only error detection
- Code type: 2D Matrix
- Orientationindependence: Yes

ECC 200 alignment patterns for 32x32 square symbol – figure 1.1:

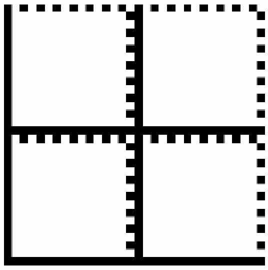


Fig. 1.1 Datamatrix 32x32 square symbol – copyright to [1]

The sample from the Table 1.1 is author property and is NOT a replacement of the standard [1]. For a complete reference please checkout ISO store for ISO/IEC 16022 standard [1]. Starting from the sample from Annex O (informative) [1], there is a description of another encodation type at byte level for word *"Ana"*:

Table 1.1 – ECC200 Paper Sample

Step 2: Error checking and correction

Error correction codewords are generated using the Reed-Solomon algorithm and appended to the encodation data stream – keep in mind, that the one should add 1 for each codeword in data, in order to obtain the ASCII encoding and the proper Reed-Solomon correction codes.

The resulting data stream is:
Data: Ana
CW No: 1 2 3 4 5 6 7 8
decimal: 66 111 98 20 66 57 160 115
hex: 42 6F 62 14 42 39 A0 73
____data____/ _______check_______/

Annex E in [1] describes the error correction process for ECC 200 and Annex E.3 in [1] gives an example of a routine to perform the calculation of the error correction codewords for the data "123456".

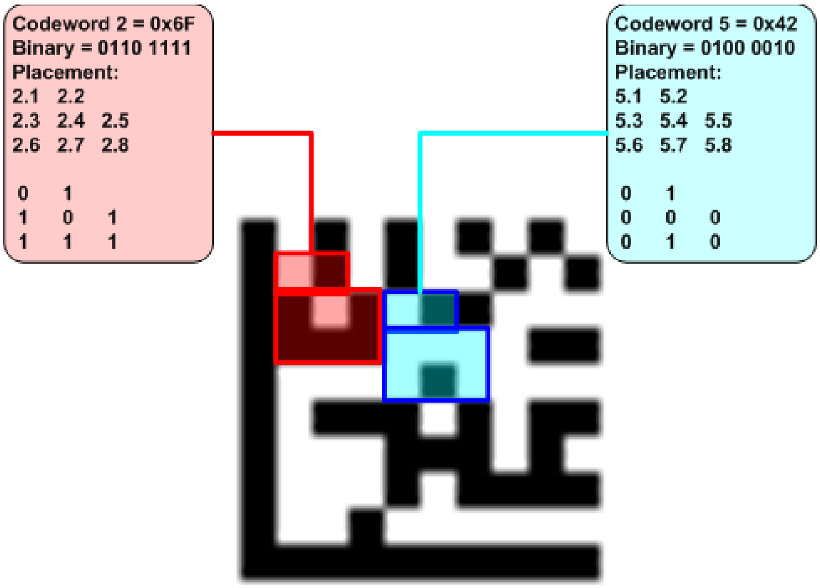
Step 3: Module placement in matrix

The final codewords from Step 2 are placed in the binary matrix as symbol characters according to the algorithm described in [1] section 5.8.1 (also see Figure F.1 and F.9 from [1]) - Where 2.1 is the first bit, 2.2 is the second bit from codeword 2, and so on:

2.1	2.2	3.6	3.7	3.8	4.3	4.4	4.5
2.3	2.4	2.5	5.1	5.2	4.6	4.7	4.8
2.6	2.7	2.8	5.3	5.4	5.5	1.1	1.2
1.5	6.1	6.2	5.6	5.7	5.8	1.3	1.4
1.8	6.3	6.4	6.5	8.1	8.2	1.6	1.7
7.2	6.6	6.7	6.8	8.3	8.4	8.5	7.1
7.4	7.5	3.1	3.2	8.6	8.7	8.8	7.3
7.7	7.8	3.3	3.4	3.5	4.1	4.2	7.6

Step 4: Actual symbol

The final Data Matrix symbol is produced by adding the finder pattern modules and converting the binary ones to black and binary zeroes to white. For instance, the second byte has value 0x6F = 0110 1111 and the fitfh codeword has value 0x42 = 0100 0010, the following figure highlights this issue:



QR – ISO 18004

QR – Quick Response is a 2D matrix symbology invented by Toyota, subsidiary Denso-Wave in 1994. The QR code is one of the most popular types of two-dimensional barcodes.

The characteristics of QR are [2]:

- Encodable character set:
  - numeric data (digits 0 - 9);
  - alphanumeric data (digits 0 - 9; upper case letters A -Z; nine other characters: space, $ % * + - . / :);
  - 8-bit byte data (JIS 8-bit character set (Latin and Kana) in accordance with JIS X 0201);
  - Kanji characters (Shift JIS character set in accordance with JIS X 0208 Annex 1 Shift Coded Representation.)
- Representation of data: A dark module is a binary one and a light module is a binary zero.
- Symbol size (not including quiet zone): 21 x 21 modules to 177 x 177 modules (Versions 1 to 40, increasing in steps of 4 modules per side)
- Data characters per symbol (for maximum symbol size – Version 40-L):
  - numeric data: 7089 characters
  - alphanumeric data: 4296 characters
  - 8-bit byte data: 2953 characters
  - Kanji data: 1817 characters
- Selectable error correction: Four levels of error correction allowing recovery of the symbol codewords:
  - L 7%
  - M 15%
  - Q 25%
  - H 30%

- Code type: 2D Matrix
- Orientation independence: Yes

The structure of QR code is in figure 1.2 and 1.3 – copyright [2] and [8] – for more details please consult the standard ISO/IEC 18004 from [2]:

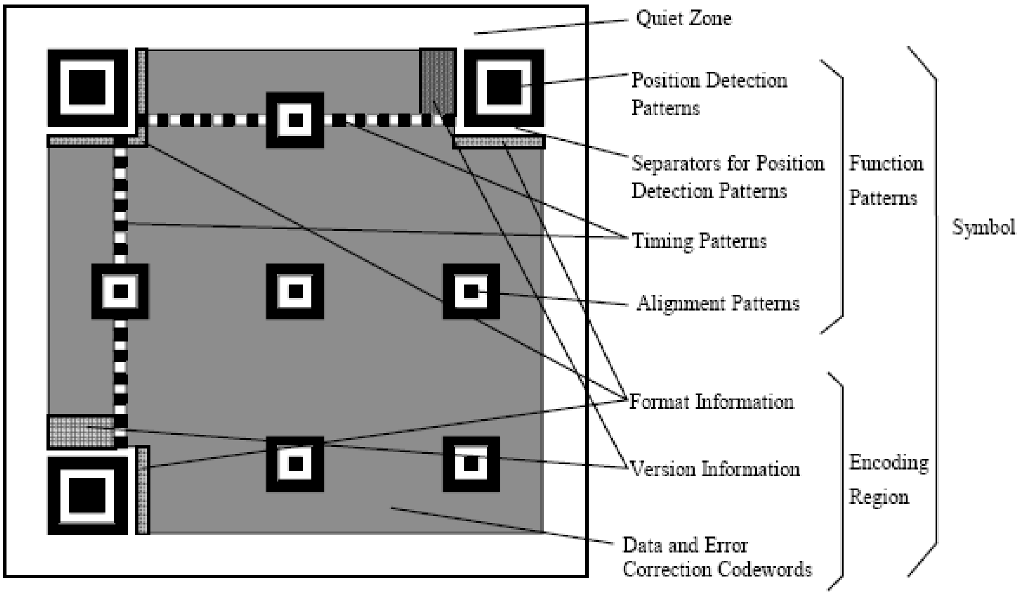


Fig. 1.2 QR Structure from standard – copyright to [2]

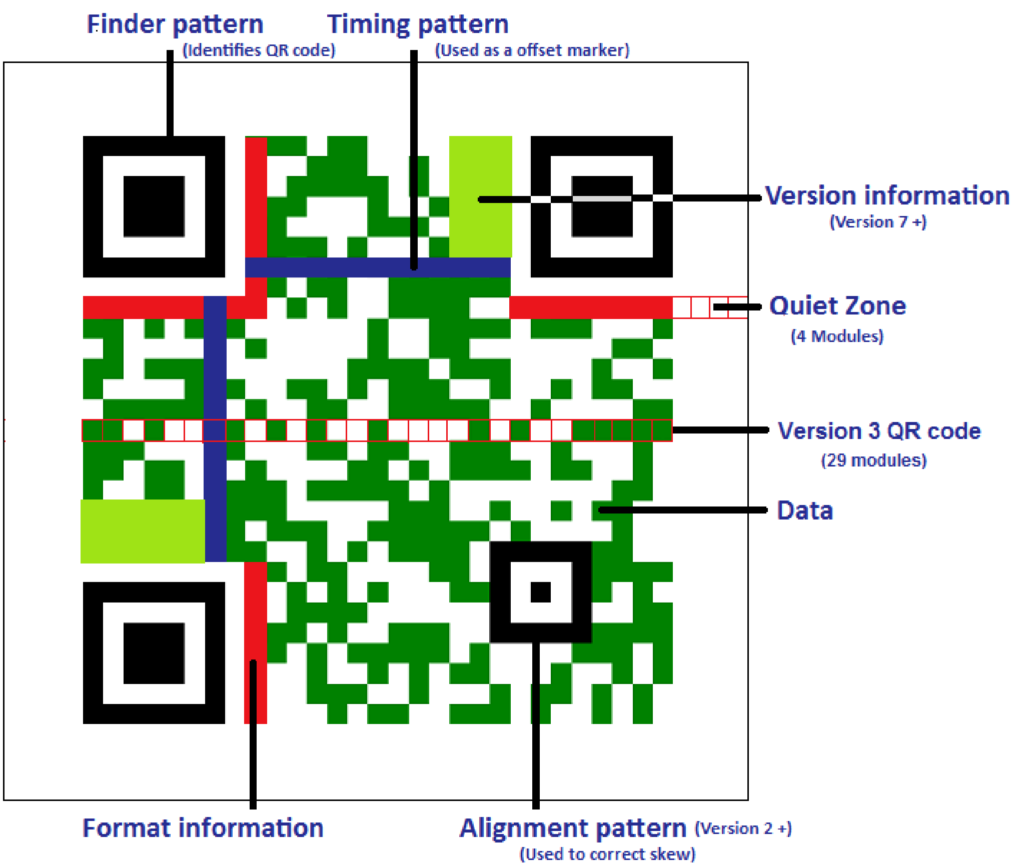


Fig. 1.3 QR Structure – copyright to [8]

Before presenting the utility of barcode in the ticket of the public transportation system, figure 1.4 shows a business card encoded in QR code – created using tool from [9]:

Fig. 1.4 Business Card with QR code [9]

Table 1.2 shows the encoded information in QR code:

Table 1.2 QR Decoding of Business Card

MECARD:**N:**Toma,Cristian;**ADR:**Calea Dorobantilor Ave., No. 15-17, Bucharest,7000,Romania;**TEL:**+40 21 319 19 00-310; **EMAIL:**cristian.toma@ie.ase.ro;**NOTE:**IT&C Security Master;**URL:**http://www.ism.ase.ro;

The following section presents the MMS and DRM topics which are the foundation for the ticket issuing and validation procedure.

2. MMS using DRM

For complete reference regarding MMS = Multimedia Message Service, is recommended, Open Mobile Alliance W@P Forum [10] and especially [11] – MMS Architecture and [14] – MMS Encapsulation protocol. For complete OMA DRM – Digital Rights Management standards [15], [16] is recommended for study [17] – OMA DRM Architecture, [18] – OMA DRM Specs, [19] – OMA DRM Content format and author paper and book which contain topics about mobile digital rights management from [20] and [21].

The figure 2.1 presents a MMS without DRM – it encapsulates in this case:

- MMS standard headers
- SMIL headers
- Text file
- Image JPG file

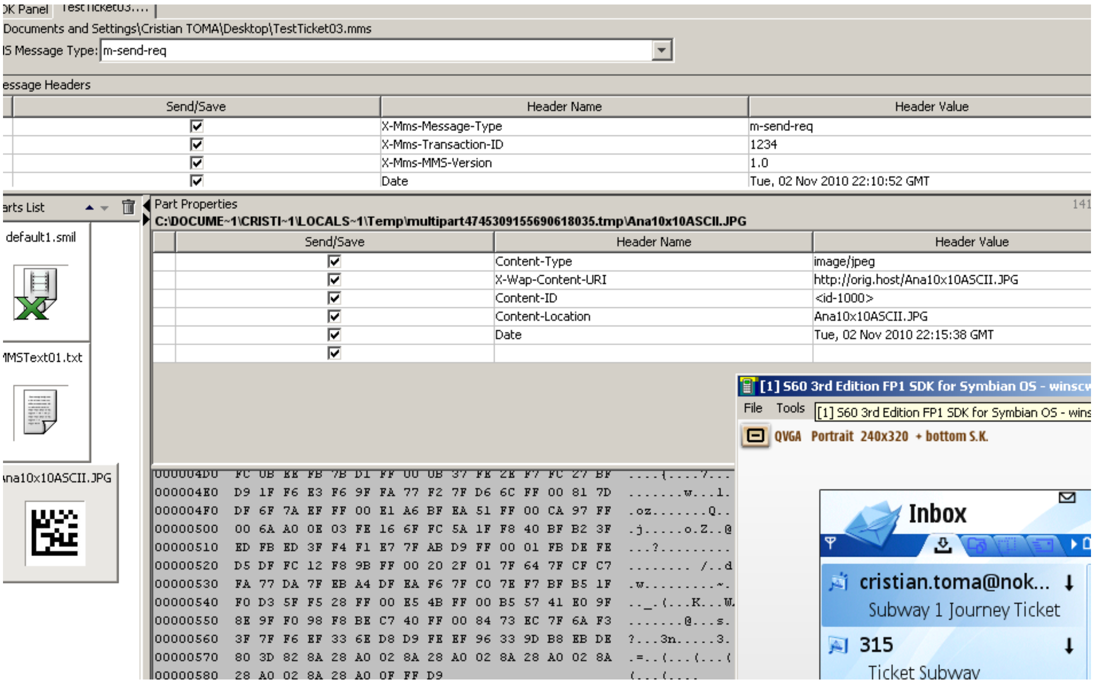


Fig. 2.1 Ticket Test MMS without DRM

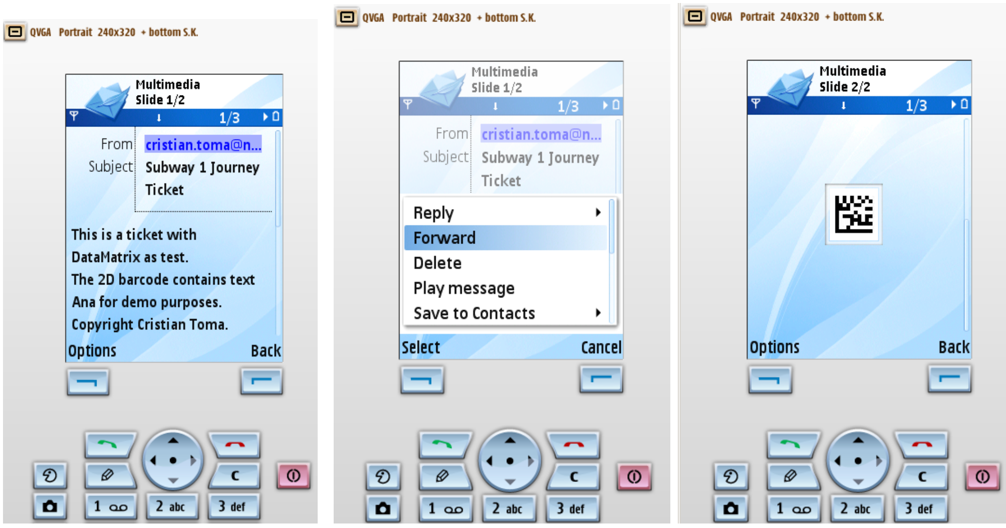


Fig. 2.2 Ticket Test MMS Content without DRM - behavior

Figure 2.2 shows the behavior of MMS encapsulated in figure 2.1. Because the MMS is not DRM prtected the “Forward” feature is activated at the mobile device.

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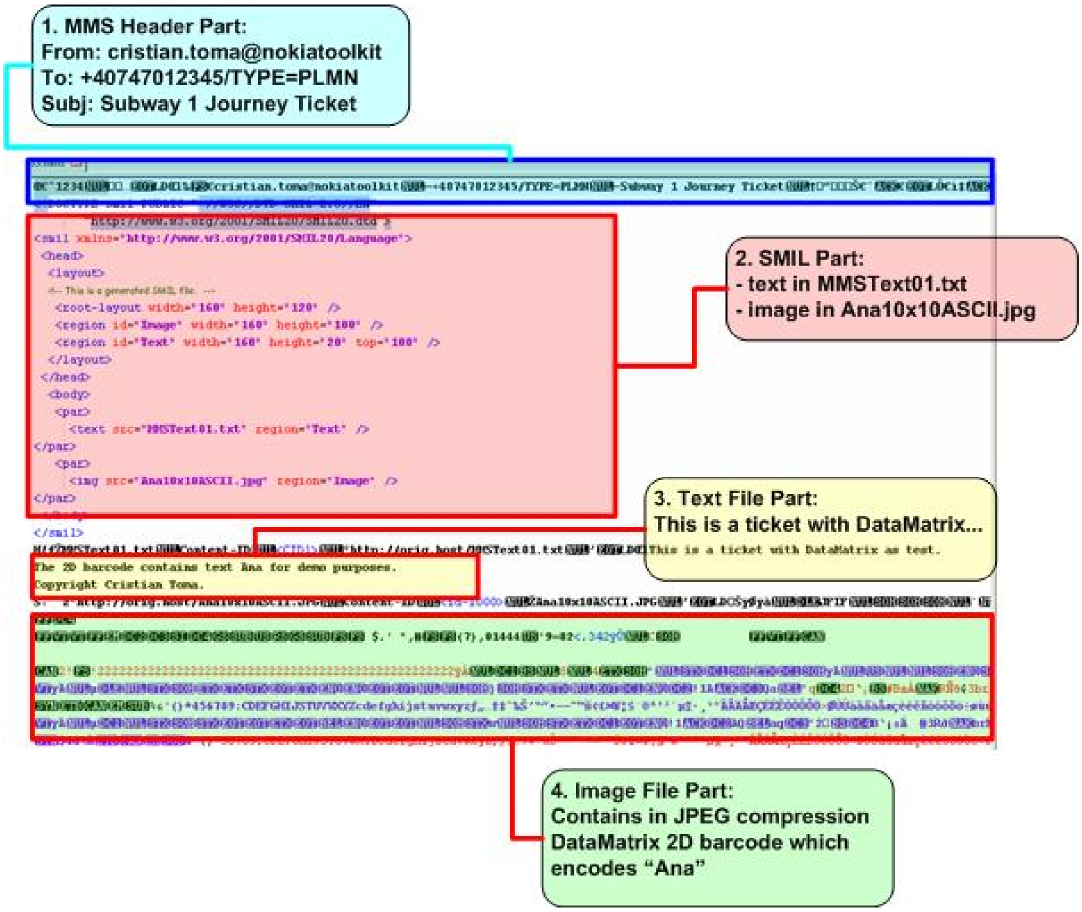
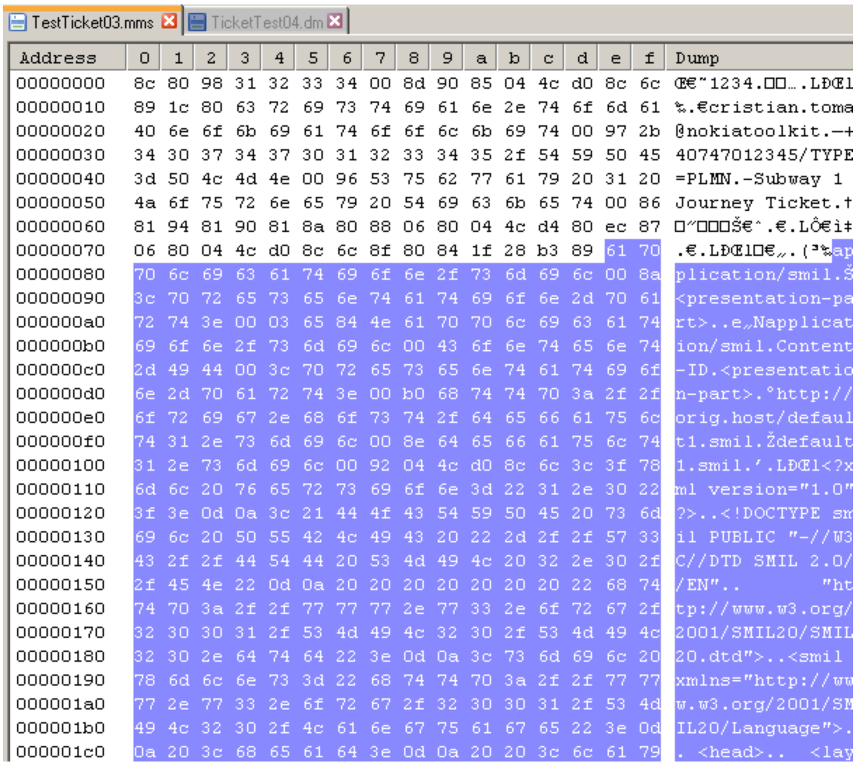


Fig. 2.3 MMS parts format



Address	0	1	2	3	4	5	6	7	8	9	a	b	c	d	e	f	Dump
00000000	8c	80	98	31	32	33	34	00	8d	90	85	04	4c	d0	8c	6c	Œ€˜1234.□□….LÐŒl
00000010	89	1c	80	63	72	69	73	74	69	61	6e	2e	74	6f	6d	61	‰.€cristian.toma
00000020	40	6e	6f	6b	69	61	74	6f	6f	6c	6b	69	74	00	97	2b	@nokiatoolkit.—+
00000030	34	30	37	34	37	30	31	32	33	34	35	2f	54	59	50	45	40747012345/TYPE
00000040	3d	50	4c	4d	4e	00	96	53	75	62	77	61	79	20	31	20	=PLMN.–Subway 1
00000050	4a	6f	75	72	6e	65	79	20	54	69	63	6b	65	74	00	86	Journey Ticket.†
00000060	81	94	81	90	81	8a	80	88	06	80	04	4c	d4	80	ec	87	□″□□□Š€ˆ.€.LÔ€ì‡
00000070	06	80	04	4c	d0	8c	6c	8f	80	84	1f	28	b3	89	61	70	.€.LÐŒl□€„.(³‰ap
00000080	70	6c	69	63	61	74	69	6f	6e	2f	73	6d	69	6c	00	8a	plication/smil.Š
00000090	3c	70	72	65	73	65	6e	74	61	74	69	6f	6e	2d	70	61	<presentation-pa
000000a0	72	74	3e	00	03	65	84	4e	61	70	70	6c	69	63	61	74	rt>..e„Napplicat
000000b0	69	6f	6e	2f	73	6d	69	6c	00	43	6f	6e	74	65	6e	74	ion/smil.Content
000000c0	2d	49	44	00	3c	70	72	65	73	65	6e	74	61	74	69	6f	-ID.<presentatio
000000d0	6e	2d	70	61	72	74	3e	00	b0	68	74	74	70	3a	2f	2f	n-part>.°http://
000000e0	6f	72	69	67	2e	68	6f	73	74	2f	64	65	66	61	75	6c	orig.host/defaul
000000f0	74	31	2e	73	6d	69	6c	00	8e	64	65	66	61	75	6c	74	t1.smil.Ždefault
00000100	31	2e	73	6d	69	6c	00	92	04	4c	d0	8c	6c	3c	3f	78	1.smil.'.LÐŒl<?x
00000110	6d	6c	20	76	65	72	73	69	6f	6e	3d	22	31	2e	30	22	ml version="1.0"
00000120	3f	3e	0d	0a	3c	21	44	4f	43	54	59	50	45	20	73	6d	?>..<!DOCTYPE sm
00000130	69	6c	20	50	55	42	4c	49	43	20	22	2d	2f	2f	57	33	il PUBLIC "-//W3
00000140	43	2f	2f	44	54	44	20	53	4d	49	4c	20	32	2e	30	2f	C//DTD SMIL 2.0/
00000150	2f	45	4e	22	0d	0a	20	20	20	20	20	20	20	22	68	74	/EN".. "ht
00000160	74	70	3a	2f	2f	77	77	77	2e	77	33	2e	6f	72	67	2f	tp://www.w3.org/
00000170	32	30	30	31	2f	53	4d	49	4c	32	30	2f	53	4d	49	4c	2001/SMIL20/SMIL
00000180	32	30	2e	64	74	64	22	3e	0d	0a	3c	73	6d	69	6c	20	20.dtd">..<smil
00000190	78	6d	6c	6e	73	3d	22	68	74	74	70	3a	2f	2f	77	77	xmlns="http://ww
000001a0	77	2e	77	33	2e	6f	72	67	2f	32	30	30	31	2f	53	4d	w.w3.org/2001/SM
000001b0	49	4c	32	30	2f	4c	61	6e	67	75	61	67	65	22	3e	0d	IL20/Language">.
000001c0	0a	20	3c	68	65	61	64	3e	0d	0a	20	20	3c	6c	61	79	. <head>.. <lay

Fig. 2.4 MMS binary format

The figure 2.3 shows the main parts of the MMS and 2.4 is the binary form representation in hex:

Table 2.1 – Binary representation of MMS

8C 84 .... Message type - MMS Message of type: *m-retrieve-conf:* A message received by an MMS device containing MMS media content. For *m-send-req:* A message sent from an MMS device containing MMS media content should be the value: **0x8C 0x80** .... **8D 90** .... MMS Version **85 04 4C D0 8C 6C** – time and date in TLV ASN.1 DER format with values in secs from 1970 => aprox 357982 hours => 14915 days => 40.86 years => year 2010 sometimes in november **89 1c 80 63 72 69 73 74 69 61 6e 2e 74 6f 6d 61 40 6e 6f 6b 69 61 74 6f 6f 6c 6b 69 74** – 0x1c bytes length of 'From' field – 0x89 with value: cristian.toma@nokiatoolkit **00** – the fields separator **97 2b 34 30 37 34 37 30 31 32 33 34 35 2f 54 59 50 45 3d 50 4c 4d 4e** – tag 0x97 is field 'To' with the value: +40747012345/TYPE=PLMN **00** – the fields separator **96 53 75 62 77 61 79 20 31 20 4a 6f 75 72 6e 65 79 20 54 69 63 6b 65 74** – tag 0x96 is field 'Subject' with value: Subway 1 Journey Ticket **00** – the fields separator **...** **SMIL Part - Synchronized Multimedia Integration Language to control the presentation of the parts of MMS message.** **...** **TEXT Part – from file 'MMSText01.txt' with content: "This is a ticket with DataMatrix as test.** **The 2D barcode contains text Ana for demo purposes.** **Copyright Cristian Toma."** **...** **IMAGE Part – binary JPEG encodetion of DataMatrix for word "Ana"**

The proposed model for 2D barcodes distribution is to generate OMA DRM MMS – minimum with "forward-lock" for each issued ticket – see figure 2.5 for different MMS delivery in terms of DRM.

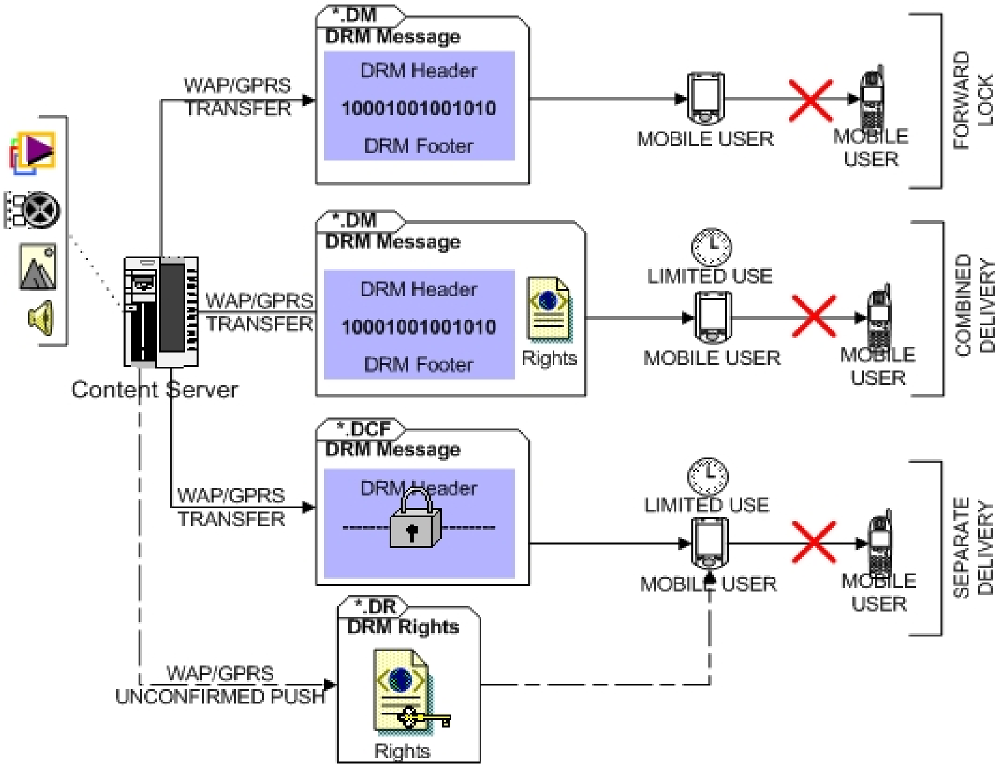


Fig. 2.5 DRM Models for MMS delivery

According to the OMA DRM standards and represented in figure 2.5, there are three DRM models for the content delivery:

- *Forward-lock* – the content provider sends to the mobile browser a binary file (image, movie, game or application) with special header and footer like in table 2.2 with "*dm*" extension. The mobile browser launches an application called the DRM agent that allows the browser to display and play the m-content without a "*Send*" option, so the end-user has no possibility of forwarding the content to another device via Bluetooth or MMS.

Table 2.2–Forward-lock Representation of "dm" file

--boundary-1 **Content-type: image/jpeg** **Content-Transfer-Encoding: binary** ÿØÿà…Binary representation of the M-CONTENT **--boundary-1--**

- *Combined-delivery* – before the binary content there is an XML representation of the "rights object" like in table 2.3 (encapsulated also in a "dm" file), which allows the browser to play only 3 times between 01.10.2010 – 01.12.2010 and does not allow it to forward the m-content.

Table 2.3–Combined Delivery Representation of “dm” file

```
--boundary-1
Content-type: application/vnd.oma.drm.rights+xml
Content-Transfer-Encoding: binary

<o-ex:rights
  xmlns:o-ex="http://odrl.net/1.1/ODRL-EX"
  xmlns:o-dd="http://odrl.net/1.1/ODRL-DD"
  xmlns:ds="http://www.w3.org/2000/09/xmldsig#/">
  <o-ex:context>
    <o-dd:version>1.0</o-dd:version>
  </o-ex:context>
  <o-ex:agreement>
    <o-ex:asset> <o-ex:context>
        <o-dd:uid>cid:http://content-id-here</o-dd:uid>
     </o-ex:context></o-ex:asset>
    <o-ex:permission>
      <o-dd:play>
         <o-ex:constraint>
           <o-dd:count>3</o-dd:count>
           <o-dd:datetime>
            <o-dd:start>2010-10-01T20:59:10</o-dd:start>
            <o-dd:end>2010-12-01T20:59:10</o-dd:end>
           </o-dd:datetime>
         </o-ex:constraint>
      </o-dd:play>
    </o-ex:permission>
  </o-ex:agreement>
</o-ex:rights>

--boundary-1
Content-type: image/jpeg
Content-ID: <http://content-id-here>
Content-Transfer-Encoding: binary

ÿØÿà…Binary representation of the M-CONTENT
--boundary-1--
```

Separate-delivery – the model allows the content provider to send the m-content that is encrypted with a symmetric key as in table 2.4 and 2.5. Therefore, within the separate delivery model, the content provider first sends the binary encrypted data with a header, encapsulated as in table 2.4 and figure 2.5 in a “dcf” file. The browser of the mobile device requests or receives the “rights object” file (the XML encapsulated in a “dr” file) from the URL included in “Rights-Issuer” field from “dcf” file. The rights object, if not request, can be pushed using WAP (Wireless Application Protocol) MMS – Multimedia Message Service or Push message (SI – Service Indicator or SL – Service Locator) mechanisms.

Table 2.4–Separated Delivery Representation of "dcf" file

→image/jpegcid:http://content-id-here gŽŒ┼Encryption-Method: AES128CBC
Content-Name: "NameOfContent"
Rights-Issuer: http://rights-issuer.com/content
Content-Description: "DescriptionOfContent"
Content-Vendor: "VendorName"
Icon-Uri: http://vendor.com/content-icon.gif
"¶{…Binary encrypt representation of the M-CONTENT using AES-Rijndael symmetric key algorithm in CBC mode

Table 2.5–Separated Delivery Representation of "dr" file

```
<?xml version="1.0" encoding="utf-8"?>
<!DOCTYPE o-ex:rights PUBLIC "-//OMA//DTD DRMREL 1.0//EN"
    "http://www.oma.org/dtd/dr">
<o-ex:rights
   xmlns:o-ex="http://odrl.net/1.1/ODRL-EX"
   xmlns:o-dd="http://odrl.net/1.1/ODRL-DD"
   xmlns:ds="http://www.w3.org/2000/09/xmldsig#/">
  <o-ex:context>
    <o-dd:version>1.0</o-dd:version>
  </o-ex:context>
  <o-ex:agreement>
    <o-ex:asset>
      <o-ex:context>
        <o-dd:uid>cid:http://content-id-here</o-dd:uid>
      </o-ex:context>
      <ds:KeyInfo>
       <ds:KeyValue>
        joVbFmkmi3bSO6gC98HE1Q==
      </ds:KeyValue>
     </ds:KeyInfo>
    </o-ex:asset>
  <o-ex:permission>
    <o-dd:play>
      <o-ex:constraint>
        <o-dd:count>2</o-dd:count>
        <o-dd:datetime>
          <o-dd:start>2006-09-27T20:59:10</o-dd:start>
          <o-dd:end>2007-09-27T20:59:10</o-dd:end>
        </o-dd:datetime>
      </o-ex:constraint>
    </o-dd:play>
  </o-ex:permission>
  </o-ex:agreement>
</o-ex:rights>
```

In conclusion, there are two ways of delivering the content rights object to the user, taking into consideration the number of files that are sent to the mobile device:

- to the consuming devices, together with media object (DRM Forward Lock and Combined Delivery Model);

- the rights separately from media content (DRM Separate Delivery Model).

Regardless of which of the three models is implemented a *download descriptor file* such as in table 2.6 can be used in order to improve the user experience.

Table 2.6–Download Descriptor Representation "dd" file

```
<media xmlns="http://www.openmobilealliance.org/xmlns/dd">
   <DDVersion>1.0</DDVersion>
   <name>Name Of Product</name>
   <size>1234</size>
   <type>image/jpg</type>
   <vendor>Media Vendor Company</vendor>
   <description>Description</description>
   <objectURI>http://object-url</objectURI>
   <iconURI>http://icon-url</iconURI>
   <infoURL>http://info-url</infoURL>
   <nextURL>http://next-url</nextURL>
   <installNotifyURI>
     http://install-notify-url
  </installNotifyURI>
  <installParam>-param1 -param2</installParam>
</media>
```

The mobile device downloads the download descriptor file and the browser is redirected to the URL (the address between "<**objectURI**>" tag from "dd" file – table 2.6) that contains or generates the "dm" or "dcf" file depending on which of the DRM models present. The table 2.7 presents the MIME (Multipurpose Internet Mail Extensions) media types of the objects, according to the DRM message format.

Table 2.7–MIME media types

DRM method	**MIME media types**
Forward-lock	application/vnd.oma.drm.message
Combined delivery	application/vnd.oma.drm.message application/vnd.oma.drm.rights+xml
Separate delivery	application/vnd.oma.drm.rights+xml application/vnd.oma.drm.rights+wbx ml application/vnd.oma.drm.content

The DRM message is based on a MIME multipart composite type in which one ore more objects are combined in a single body. The body of the DRM message must be according to the body of the multipart media type defined in RFC 2045 and 2046. The Digital Right Management message must contain one or two body parts, one for each object. If HTTP (Hyper Text Transfer Protocol) or a MIME compliant protocol is used to transport the Digital Right Management message, the boundary delimiter must be included as a parameter within the media type definition.

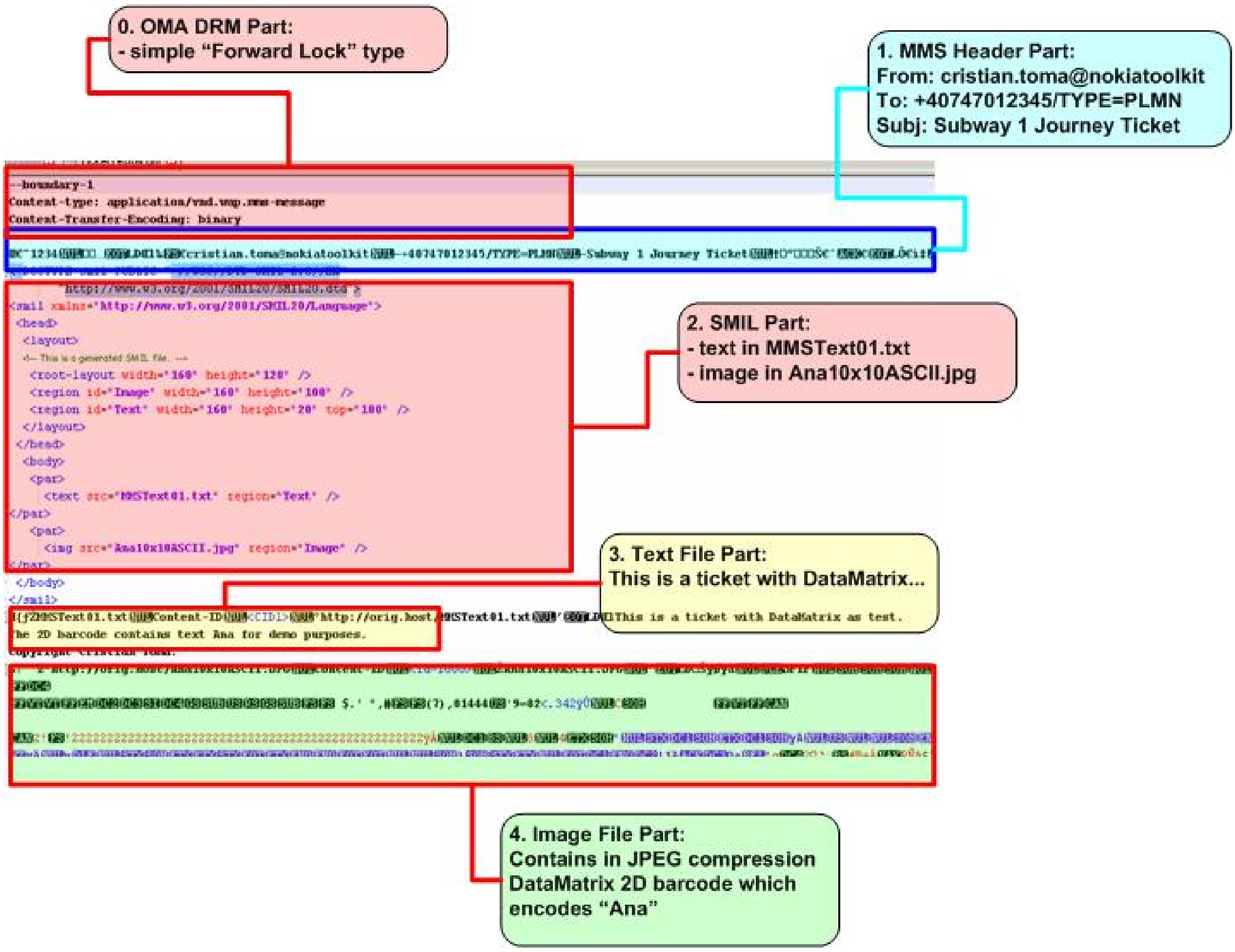
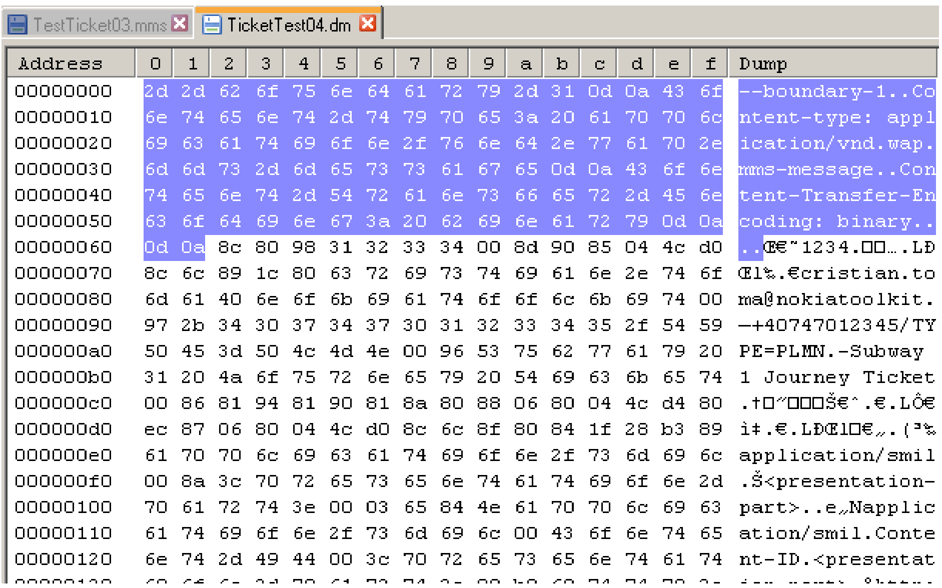


Fig. 2.6 MMS with DRM main Parts



Address	0	1	2	3	4	5	6	7	8	9	a	b	c	d	e	f	Dump
00000000	2d	2d	62	6f	75	6e	64	61	72	79	2d	31	0d	0a	43	6f	--boundary-1..Co
00000010	6e	74	65	6e	74	2d	74	79	70	65	3a	20	61	70	70	6c	ntent-type: appl
00000020	69	63	61	74	69	6f	6e	2f	76	6e	64	2e	77	61	70	2e	ication/vnd.wap.
00000030	6d	6d	73	2d	6d	65	73	73	61	67	65	0d	0a	43	6f	6e	mms-message..Con
00000040	74	65	6e	74	2d	54	72	61	6e	73	66	65	72	2d	45	6e	tent-Transfer-En
00000050	63	6f	64	69	6e	67	3a	20	62	69	6e	61	72	79	0d	0a	coding: binary..
00000060	0d	0a	8c	80	98	31	32	33	34	00	8d	90	85	04	4c	d0	..Œ€˜1234.□□….LÐ
00000070	8c	6c	89	1c	80	63	72	69	73	74	69	61	6e	2e	74	6f	Œl‰.€cristian.to
00000080	6d	61	40	6e	6f	6b	69	61	74	6f	6f	6c	6b	69	74	00	ma@nokiatoolkit.
00000090	97	2b	34	30	37	34	37	30	31	32	33	34	35	2f	54	59	—+40747012345/TY
000000a0	50	45	3d	50	4c	4d	4e	00	96	53	75	62	77	61	79	20	PE=PLMN.–Subway
000000b0	31	20	4a	6f	75	72	6e	65	79	20	54	69	63	6b	65	74	1 Journey Ticket
000000c0	00	86	81	94	81	90	81	8a	80	88	06	80	04	4c	d4	80	.†□”□□□Š€ˆ.€.LÔ€
000000d0	ec	87	06	80	04	4c	d0	8c	6c	8f	80	84	1f	28	b3	89	ì‡.€.LÐŒl□€„.(³‰
000000e0	61	70	70	6c	69	63	61	74	69	6f	6e	2f	73	6d	69	6c	application/smil
000000f0	00	8a	3c	70	72	65	73	65	6e	74	61	74	69	6f	6e	2d	.Š<presentation-
00000100	70	61	72	74	3e	00	03	65	84	4e	61	70	70	6c	69	63	part>..e„Napplic
00000110	61	74	69	6f	6e	2f	73	6d	69	6c	00	43	6f	6e	74	65	ation/smil.Conte
00000120	6e	74	2d	49	44	00	3c	70	72	65	73	65	6e	74	61	74	nt-ID.<presentat

Fig. 2.7 MMS with DRM binary format

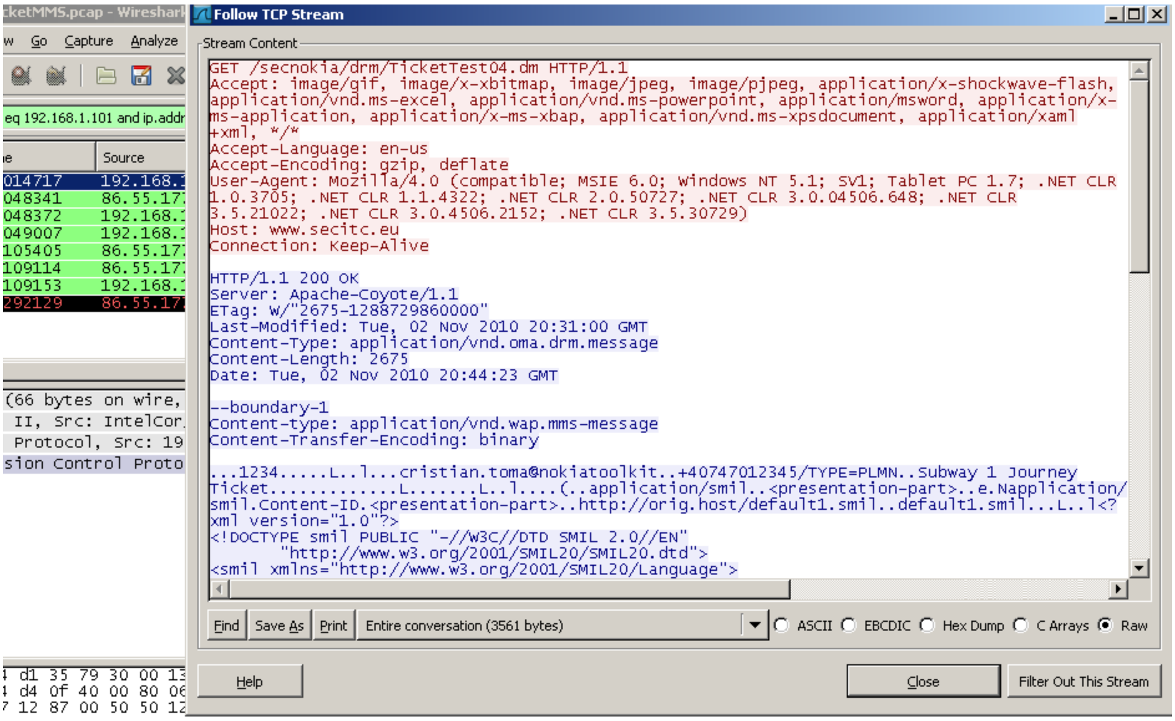


Fig. 2.8 MMS with DRM HTTP analysis

Figure 2.6 is related with figure figure 2.3 but because of OMA DRM Forward Lock, it is an extra with text:

Table 2.8 OMA Header for Forward Lock

--boundary-1 **Content-type: application/vnd.wap.mms-message** **Content-Transfer-Encoding: binary**

Figure 2.7 is related with figure 2.4 with the same binary interpretation but with the binary bytes as plus for the text from table 2.8.

3. The Subway 2D Barcode Automatic Ticketing System – 2D BATS

The speed and the accuracy of reading process is a MUST in Public Transportation Ticketing Systems. Figure 3.1 presents the evolution of QR code – copyright [22]:

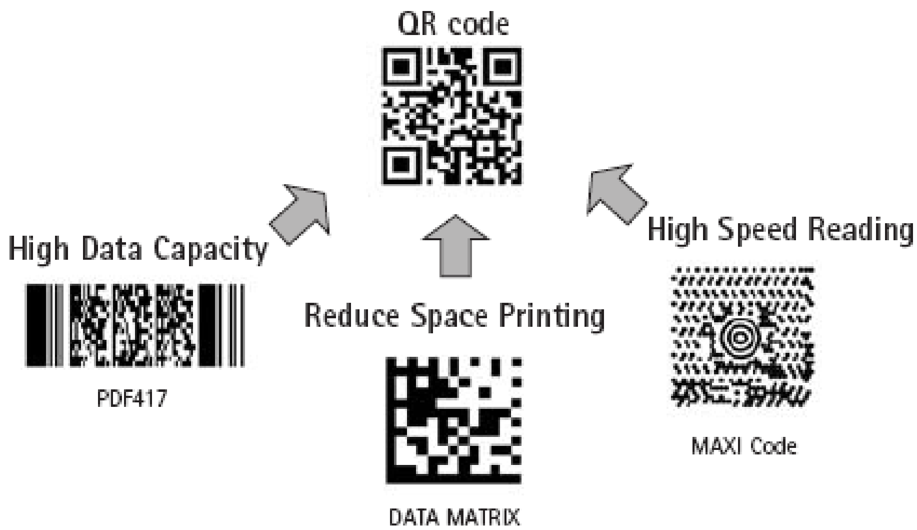


Fig. 3.1 QR Code Evolution – copyright to [22]

In 2D BATS will be used QR code for encoding tickets. The ticket representation is in table 3.1, 3.2 and figure 3.2:

Table 3.1 Text Preparation of anonymous ticket before Base64

METICKET:**N:**-;**ADR:**-;**TEL:**-;**EMAIL:**-; **ENCINFO:***Base64*(***Encrypt(line:blue;sdate:20101101Z112345;edate:20101201Z112345;nojrns:1)***);**PTSYS:** Boston Subway;**URL:** http://www.mbta.com/;

Table 3.2 Text Preparation of anonymous ticket after Base64

METICKET: **N:**-; **ADR:**-; **TEL:**-; **EMAIL:**-; **ENCINFO:**bGluZTpibHVlO3NkYXRlOjIwMTAxMTAxWjExMjM0NTtlZGF0ZToyMDEwMTIwMVoxMTIzNDU7bm9qcm5zOjE=;**PTSYS:** Boston Subway;**URL:** http://www.mbta.com/;

Fig. 3.2 QR code for 1 journey ticket scale 2:1

In terms of encapsulated info table 3.1 and 3.2 are self descriptive. In figure 3.2, the QR encoding was at byte level, version 9, correction level M (9-M).

The Base64 algorithm is highlighted in figure 3.3 for sample word "Man" and the "Encrypt(…)" function from table 3.1, is proprietary for each public transportation system.

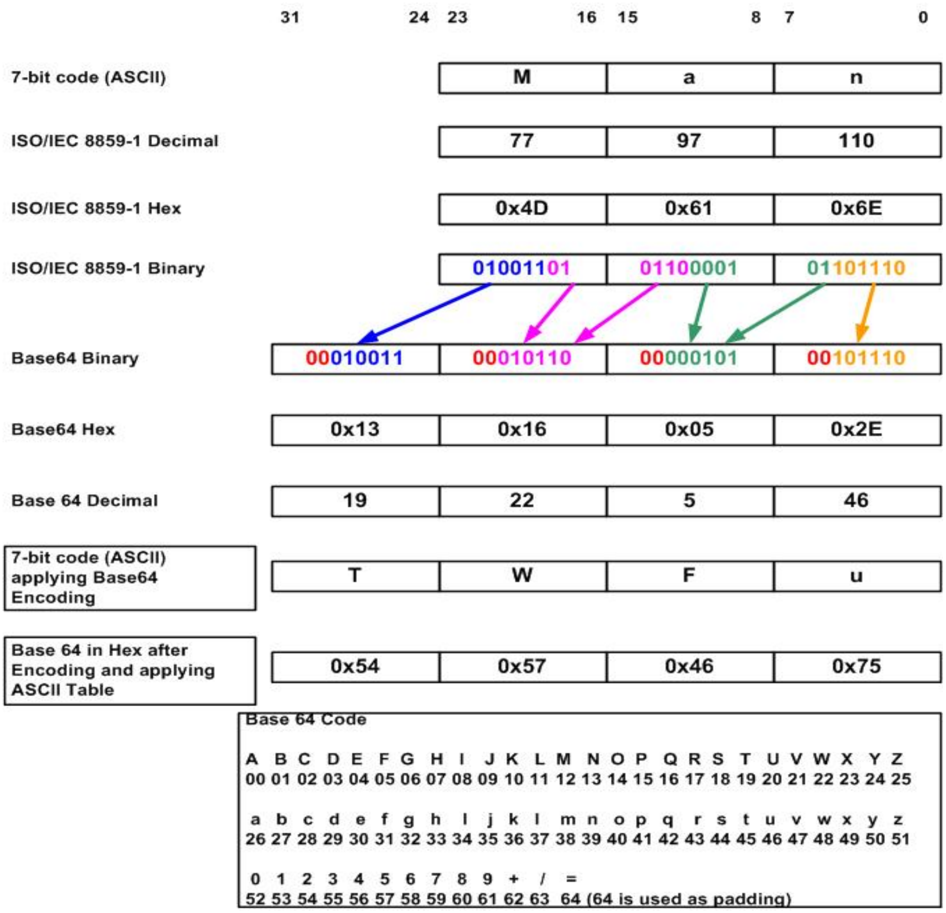


Fig. 3.3 Base64 for word "Man"

J A Q M
Vol. 5
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Winter
2010

The 2D BATS Archiecture is presented in figure 3.4.

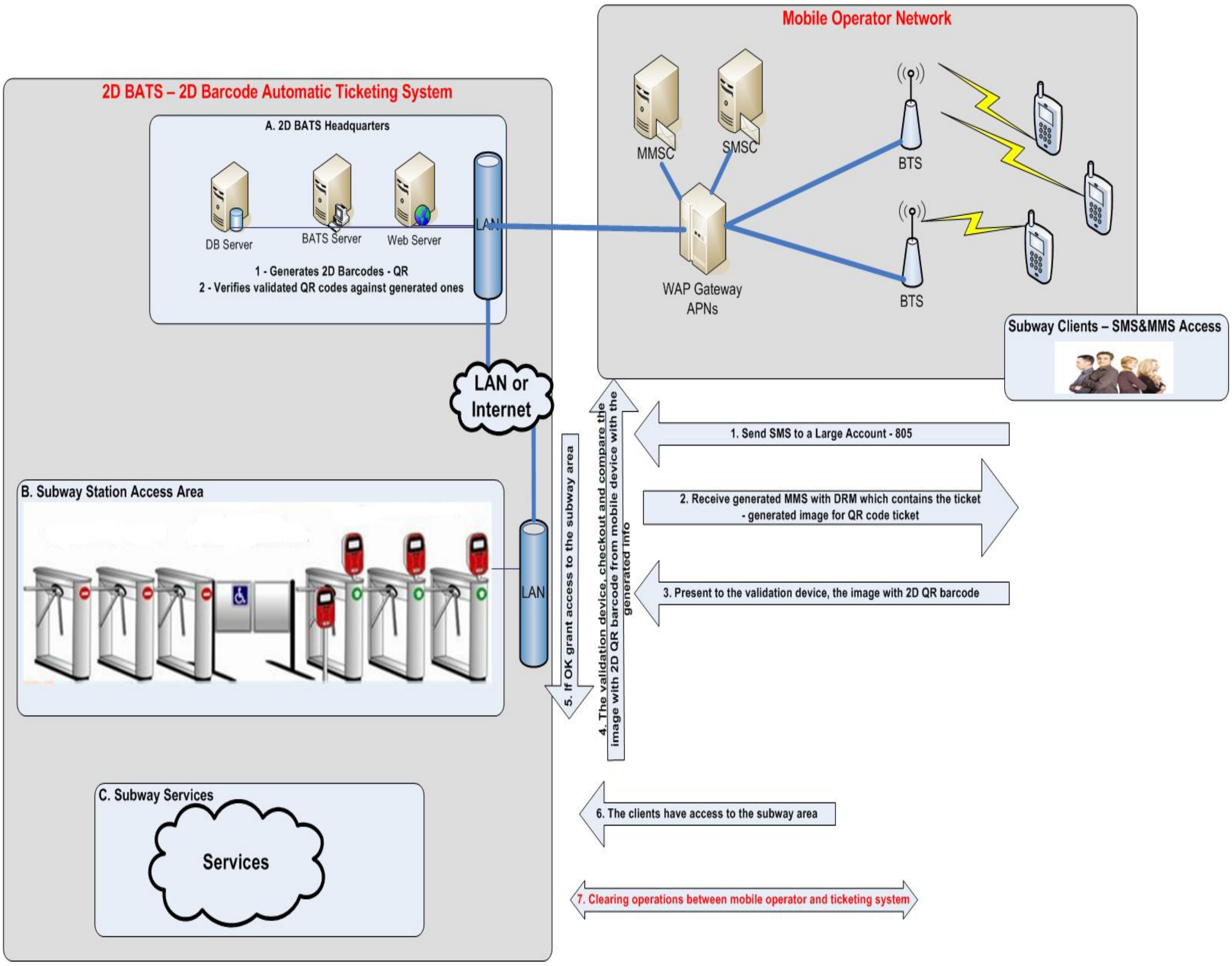

Fig. 3.4 2D BATS Architeture

The data flow is the following:

- The clients access via SMS a large account with premium tax fee;
- The mobile operator sends the requests to the 2D BATS back-end systems;
- The back-end systems generate the 2D barcode QR encapsulated in a MMS with OMA DRM – minimum “forward lock”;
- The MMS with DRM arrives to the clients via MMSC and the proper APNs equipments – mobile operator premises;
- The MMS is received and the clients can not send the MMS content to them – first security level;
- The clients presents the MMS to the validation devices from the subway stations;
- The validation devices decode QR code, decrypt the content of the field ***ENCINFO***, and decode from Base64 in byte arrays.
- The validation devices prefrm security checks about info encapsulated in QR code - ticket and send info to the back-end servers of 2D BATS.
- If 2D BATS back-en systems confirm that everything is OK, the access in the station is granted by the validation device to the client.

4. Conclusion and Statistics

The main advantages of 2D BATS solution are: the optimization, low cost and speed of the distribution chain which is in charge for the tickets issuing.

Regarding the tests performed on varios validation devices the table 4.1 presents the results:

Table 4.1 Comparison in terms of seconds for the validation devices

No	Device OS	Processor	Camera	DataMatrix Speed Read+Process	QR Speed Read+Process
1	Symbian 9.2 3rd Edition	Dual Core ARM 11 332 MHZ	Camera Resolution - 2582 x 1944 px CMOS Sensor - 5.0 Megapixel	1.23 s	1.04 s
2	Symbian 9.4 5th Edition	Single Core ARM 11 434 MHZ	Camera Resolution - 2048 x 1536 px CMOS Sensor - 3.2 Megapixel	0.96 s	0.85 s
3	Android OS, v2.1	ARM Cortex A8 1GHz	CMOS 5 MP, 2592 x 1944 pixels	0.97 s	0.67 s
4	Microsoft Windows Mobile 7	Qualcomm Snapdragon QSD8250 1 GHz	CMOS 5 MP, 2592x1944 pixels	0.98 s	0.91 s

It is obvious that the most important features for the validation process speed are: the camera type, the processor type and the operating system type. In table 4.1 there are the time in seconds spent for reading and processing the 2D barcodes for the tickets in DataMatrix and QR symbology. The best results have been obtained with devices from the position 2 and 3 from the table 4.1.

In the future, the optimization of the barcode info, the encryption/the signing process of the sensitive info from the tickets, the DRM improvement and the frontend/backend validation process speed enhancement, and the tests on the various devices should be research topics for security issues in such kind of systems.

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