Regular paper

Testing of interworking between network terminals with FSK receivers and public exchanges providing display and related services

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Abstract—Implementation of new services in the network requires appropriate methods and tools for checking correctness of interworking between terminals and exchanges. In this article the methodology and test procedures prepared for testing terminals handling FSK protocol transmitted over the local loop for "display and related services" was described. Methodology presented here is based on ETSI standards. Test procedures were developed for services offered in Polish network. Tests cover all levels of FSK protocol. For two lower layers, separate procedures for "on-hook" and "off-hook" loop states were prepared. The procedure for "on-hook" state contains tests related to data transmission "associated" and "not associated with ringing". These procedures cover normal cases with parameter values and sequence elements complying with standards and exceptional procedures with the extreme values of the parameters and with modified elements of the sequences.

Keywords—testing methodology, display and related services, CLIP service, MWI service, SMS service, UBS solution, NBS solution, FSK protocol, Call Setup message, Message Waiting Indicator message, transmission associated with ringing, transmission not associated with ringing, data transmission prior to ringing, on-hook data transmission, off-hook data transmission, physical layer, data layer, presentation layer.

1. Introduction

In order to increase revenues, operators have to look for new strategies. One element of these strategies is providing new services, e.g., for analog subscribers. Generally, new services appear as result of development of new technologies for transfer of information. The scope of the services dedicated to analogue subscribers may be extended through use of frequency shift keying (FSK) protocol over analogue subscriber line.

Following worldwide trends, Polish operators try to adjust their service offers to ones of the most European operators. As result of this, the list of services is modified and new services, better suited to the present and future needs are implemented. One of such services is *Short Message Service* (SMS), which up to now has been available to GSM subscribers only. *Calling Line Identification Presentation during Call Waiting* (CLIP CW) and *Message Waiting Indication* (MWI) supplementary services, being standard services of digital networks are very attractive for analogue subscribers, too.

The present offer of the dominant Polish operator Telekomunikacja Polska SA (TP SA), for analogue subscribers, includes new services, such as: *Calling Line Identification Presentation* (CLIP), *Calling Line Identification Restriction* (CLIR), and services mentioned above: CLIP CW, MWI and SMS, called display and related services.

Introduction of these services gives many important functions for analogue subscribers, offered earlier exclusively to ISDN and GSM subscribers. The display and related services, especially MWI (concerning voice mail service) and SMS (which is very popular in GSM networks), will be probably widely used by analogue subscribers and likely as popular as in GSM networks.

2. New needs for subscriber terminals testing

Introduction of new services stimulates development of new test methods and procedures for evaluating correctness of interworking between terminals and public switches during provision of these services.

Services implemented in Polish network cover most data transmission cases, applied also in many other services utilizing the FSK protocol. Implementation of the CLIP CW service means that test procedures for data transmission in "off-hook" state must be prepared. Introduction of the MWI service into the network causes that the terminals have to be tested for data transmission in a "not associated mode". To assure the required quality of transmission for the short message (SM), the terminals should be tested for data transmission in an "associated mode".

From this reason, development of test method to verify handling FSK protocol, by terminals equipped with FSK receivers, during realization of the CLIP CW, MWI and SMS services was done in 2003 in the Switching Systems Department. It was one of the tasks of the work: *"Development of modern measurement method harmonized with the requirements of European Union, concerning network terminals connected to the PSTN network"*, performed last year at the National Institute of Telecommunications

in Warsaw. As a result of this task, both the methodology and testing procedures were developed. Final results have considerable practical use.

Within the above mentioned work, basic problems concerning testing of terminals handling FSK protocol were solved, in particular detailed tests were defined. These tests may be used to check the functional and electrical parameters of FSK receivers and to verify timers applied to data transmission during realization of the above listed services.

Depending on the service and operators's requirements, appropriate set of tests was prepared concerning FSK protocol data transmission in a various states of analogue line and in various modes. They include cases of data transmission given in ETSI standards [9] and [10].

It should be underlined that the number of data transmission cases included in tests is significant, but it does not comprise all possible data transmission cases and the tests are concentrated on the solutions required in the Polish public network.

The article presents general description of results obtained.

3. CLIP CW, MWI and SMS services as examples of display and related services implementation

Overall description of the CLIP CW service, including controlling procedures, is presented in the ETSI standards [1–3] and in the document [16]. According to these documents, the *Call Waiting Tone* (CWT), followed by the *Dual Tone Alerting Signal* (DTAS), should be sent to the controlling user, when he is engaged in communication with the second subscriber and the other subscriber is attempting to obtain connection to his telephone number. The DTAS signal informs the terminal of the controlling user that data transmission will be started. The CLIP function shall apply to the line in "off-hook" state. The CLIP CW service is related to the *Call Setup* message. Parameters of this message are defined in [6].

The MWI supplementary service is offered together with the *Call Forwarding to Voice Mail* (CF-VM) service. This service is typically used between a voice mailbox service provider (controlling user) and a user of the voice mailbox service (receiving user). The MWI service enables the network, upon the request of controlling user, to indicate to the receiving user, that there is at least one message waiting in voice mail. The message may be sent in immediate or deferred modes. For analogue subscribers, a visual indicator and an informative message can be displayed on their terminals. Data transmission not associated with ringing is used to support MWI service. The MWI message is used to handle information related to messages in message system. Detailed description of this service is given in document [7]. Parameters of this message are defined in [6].

In accordance with the national requirements, the CLIP CW and MWI services should operate in standard modes described in the above mentioned documents.

The SMS supplementary service enables the originating user to send a SM of limited size to a destination user via short message service center (SM-SC). Messages may be input to the SM-SC by means of a suitable telecommunication service either from the fixed network, e.g., speech, telex, facsimile, etc. or from a mobile network.

The SMS service may operate as user based solution (UBS) or network based solution (NBS). In UBS solution, messages are transported via a SM-SC using normal voice band call through the network using in-band signalling. The UBS solution is supported by Protocol 1 and Protocol 2, specified in [15]. It is a network operator's option to choose which protocol is used. According to Polish requirements, Protocol 1 should be used. In UBS solution the exchange participates in data transmission in a limited scope. Data are transmitted transparently through the network between the terminals (of originating and terminating user) and the SM-SC. The first role of the exchange is to set up the call in order to send SM from originating user and in order to receive SM by terminating user. The second role is to support CLIP function during SM delivery from SM-SC to SM-TE. The NBS solution uses the SMS message, specified in [6].

4. FSK protocol features used for implementation of display and related services

Implementation of new services in the network depends on whether the terminals and the exchange can serve the FSK protocol in "on-hook" and "off-hook" states and whether they support data transmission (associated and not associated with ringing), in accordance with the requirements for particular service. The fundamental principles of interworking between terminals and public exchanges are described in ETSI standards [4, 9 10]. Full scope of the messages and parameters used in the display and related services is presented in [6]. In the Polish network, only basic parameters related to the CLIP and the MWI services are transmitted currently.

According to the national requirements, the following parameters should be used for CLIP CW service in the *Call Setup* message:

- date and time (M),
- calling line identity (M),
- reason for absence of calling line identity (M),
- calling party name (O),
- reason for absence of calling party name (O),
- called line identity (O),
- first called line identity (O),
- call type (O).

The following notes apply:

1. "M" means mandatory parameter, "O" optional parameter (for use in national network).
2. Generally, the ISUP 1 protocol is implemented in national network (ISUP 2 exist actually only in part of the network), so it is not possible to send the calling party name and reason for absence of calling party name parameters.

In accordance with the national requirements, the following parameters should be used for MWI service in MWI message:

- date and time (M),
- visual indicator (M),
- number of messages (M),
- calling line identity (O),
- reason for absence of calling line identity (O),
- calling party name (O),
- reason for absence of calling party name (O).

Notes listed above are valid also here.

When SMS service is supported by the UBS solution, the most important items for this service are specified in [14] (containing service description) and [15] (describing short message communication between a fixed network short message terminal equipment (SMTE) and SM-SC). The document [6] is important only for the CLIP function. FSK protocol described there consists of different messages than protocol described in above mentioned standards.

According to the [14], to send and to receive short message a voice band communication path is established in the PSTN/ISDN between SM-TE and SM-SC using basic call control procedures. The SM transfer is split into two steps, the SM transmission (transfer of a SM from the sender to the SM-SC) and SM delivery (transfer of a SM from the SM-SC to the receiver).

In the first step (SM submission), SM-TE establishes a call to the SM-SC to submit the SM to the SM-SC, which acts following the store and forward principle. The network shall provide the caller ID (CLI) of the SM-TE to the SM-SC (SM-SC uses this information to identify the SM-TE). After the voice band connection between SM-TE and SM-SC has been established, the end-to-end SM data transfer phase is entered for short message transfer. After the SM has been transferred, the connection is released.

In the second step (SM delivery), the SM-SC establishes a call to the SM-TE to deliver the SM to the SM-TE. In this case, the network shall provide the CLI of the SM-SC to the SM-TE. The SM-TE uses this CLI information to identify and connect an incoming call from the SM-SC. As in the first step, the short message is transmitted from SM-SC to the SM-TE after the voice band connection has been established. After the SM has been transferred, the connection between SM-SC and SM-TE is released.

In case of PSTN access, the CLI function is provided with FSK signalling according to documents [4] and [6], describing the end-to-end interworking and the protocol between SM-TE and the exchange. Than, from the exchange point of view, the FSK protocol is the same for SMS and CLIP services.

In accordance with the national requirements, the end-to-end interworking between SM-TE and SM-SC should be provided with the FSK protocol according to [14] and [15] and between SM-TE and the public exchange according to [6]. It is important, that the national requirements comprise only end-to-end interworking between SM-TE and the exchange. Subjects concerning interworking between SM-TE and SM-SC are beyond scope of these requirements.

5. Principles of testing of terminals equipped in FSK receivers

Till now, international standard bodies have not published appropriate documents containing detailed test procedures, which allow to test the display and related services (in particular CLIP CW, MWI and SMS services).

The testing process is currently covered by ETSI standards [11–13]. These documents contain some indications of the organization and design of tests, but do not include explicit requirements for testing. Although current versions of these documents do not comprise all information needed for testing, they are nevertheless important reference points for methodology.

Document [11] provides the PICS proforma for the subscriber line protocol for support of PSTN display services at local exchange in "on-hook" and "off-hook" states. The first state is defined in [6] and [9] in compliance with the relevant requirements and in accordance with the relevant guidance in ISO/IEC 9646-7[1]. The second state is defined in [6] and [10] in compliance with the relevant requirements and in accordance with the relevant guidance in ISO/IEC 9646-7[1]. It is a document, in form of a questionnaire, which should be fulfilled by product supplier. The PICS confirm conformance to a given protocol specification.

The standard [12] specifies the TSS&TP for both the "on-hook" and the "off-hook" data transmission over PSTN access for terminal equipment. In order to stay aligned with structure of the base standards, this document specifies test purposes for FSK protocol. This document contains items related to the naming convention, structure of tests, test strategy and principles of test design and execution. It comprises also items concerning general principles of testing

[1] "Information technology—Open Systems Interconnection—Conformance testing methodology and framework—Part 7: Implementation Conformance Statements", ISO/IEC 9646-7:1995.

particular layers of FSK protocol. The document does not cover interaction with other supplementary services.
According to this standard, test specifications should be divided into three parts applicable to three FSK protocol layers. The physical layer and data layer signals should be generated in "on-hook" and "off-hook" states. The presentation layer tests should comprise sequences with both correct and incorrect elements.
In scope of the test's design, the standard [12] specifies the naming convention and structure of tests. According to the convention, test name consists of the following elements: name of layer, name of service, group number and sequential number. Groups are organized according to the TSS and sequential number starts with "001", within each group. The structure of a single test consists of the following general elements: header, stimulus (e.g., pre-test conditions), reaction (action, conditions) and message structure (message containing message parameters).
Test strategy should be based on assumptions, that:

- the tests should check the correctness of transfer of each FSK protocol element,
- all messages should contain at least the mandatory parameters and the parameters should have correct values,
- neither message nor a parameter, which can lead to a "fail" or "inconclusive" verdict, should be used.

To ensure the correct reception of the message by terminal equipment (TE), the test operator should observe the TE after test execution.
Indications and the notes concerning design and execution of the tests included in standard [12] the inform, that the conformance of lower layers (the physical (PH) and data link layer (DL)) of the terminal equipment (TE) under test should be diagnosed by either proper reception or no reception of messages by the TE at the presentation layer, sent through the PH and DL layers. Absence of reception of a message may result from:

- no support of the implementation under test for that particular service or parameter,
- non-conformance of the physical layer of the TE.

In case of reception of a valid message, through a valid DL layer, the implementation under test shall activate the corresponding indicators. This assumes the proper reception of the physical signal. The test operator will evaluate the correct reception of the message, and consequently of the physical signal, by observing the reaction of the TE. The TE should react to message reception by activating indicators (e.g., a LED) or displaying the received information (for example calling line ID).
Standard [12] contains also the test purposes (TP) in outline form, which are intended to check that particular layers of the FSK protocol are correct. The test purpose consists of elements like: name of the test, references to the base standards and expected result. Each layer is covered by one group of test cases.
Standard [13] describes abstract test method and specifies the PIXIT for both the "on-hook" and "off-hook" data transmission over PSTN access for terminal equipment. Based on the abstract test method, different types of abstract service primitives (ASP) are presented, which enable to send or receive a protocol data unit (PDU), using parameters transmitted in ASPs. The structure of the ASPs fit the type of PDUs or signals to be send or received. Some ASPs contain a duration parameter. This means that by sending this ASP the corresponding signal is maintained within this duration. In the test case, the next event can only start after the signal is completely sent, i.e., at the end of its duration. Generally, the document mentioned illustrates the particular behaviour during creation of the signals (for physical layer), messages for data and presentation layer and the full sequences, using the FSK signal features as defined by corresponding parameters (i.e., mark and space frequency, level and noise).

6. Methodology of subscriber terminal testing

The methodology was developed after analysis of ETSI standards: [6, 9–12] and Polish national requirements [17] and [18].
According to these documents, methodology contains descriptions of principles for testing each service, test configurations and selected instruments used for testing. Because CLIP CW, MWI and SMS services operate in different environments (transmission modes, and loop states), it is assumed that lower layers tests will be dedicated to each layer, each transmission mode and each loop state, as separated test procedures. For tests of presentation layer separated procedures, dedicated to each service, will be used.
The testing procedure of the CLIP CW service comprises group of tests in "off-hook" state. It consists of tests specified in standard [12]. These tests should be used to check the following items:

- response of the terminal to receipt of *Call Setup* message containing correctly and incorrectly coded mandatory and optional parameters,
- response of the terminal to receipt of extremely valued signals,
- timing functions concerning signals transmission in the subscriber loop.

This procedure includes also many additional tests, not specified in standard [12], which give the possibility to check the following items:

- response of the terminal to receipt of incorrect sequences containing incorrect codes of the signal transmitted before data transmission has started (*Mark Signal*),

– response of the terminal to receipt of incorrect elements of sequences sending in presentation layer, which are not specified in [12],

– response of the terminal to the loop state change (from busy to idle state),

– electrical parameters of the terminal equipment acknowledgement (TE-ACK) signal.

Test procedure for MWI service contains group of tests executed in idle state. The testing process comprises checking data transmission not associated with ringing. It consists of tests containing the MWI message with the visual indicator parameter and other mandatory and optional parameters. These tests allow to check the response of the terminal to receipt of:

– MWI message containing correctly and incorrectly coded mandatory and optional parameters,

– extremely valued signals and timing signals for transmission in the loop.

The procedure contains standard tests which are developed in relation to tests specified in [12]. This procedure contains also non-standard tests, e.g., additional tests being out of the scope of the above mentioned standard and tests related to national requirements. Additional tests may be used to check the following items:

– response of the terminal to receipt of incorrect sequences containing incorrect codes of the signals transmitted before data transmission has started (channel seizure signal and mark signal),

– response of the terminal to receipt of incorrect elements of sequences transmitted in presentation layer, which are not specified in [12],

– response of the terminal to the loop state change (from idle to busy state).

The presentation layer testing procedure, concerning SMS service, is completely different from the proposal presented in standard [12] for this service. According to the [14], the SMS can be implemented in two ways, either as a NBS or as a UBS.
In the NBS solution a supplementary service is offered as a part of a function within the public network. In UBS solution the service is offered as a part of a function within end user equipment, which does not require any specific short message function inside the public network.
The document [12] assumes that the SMS service operates as a NBS solution and the SM message is used. Procedure developed contains tests concerning only the UBS solution, because this application will be used (according to the [14] and [15]) in the Polish network. In accordance with these documents, during realization of SMS service, except for the interworking between a TE and an exchange, direct interworking between TE (calling and called) and SM-SC and different messages (than in the UBS solution) is needed.
In the UBS solution, the outgoing message from the originating TE shall be sent to the SM-SC and shall contain the address of the receiver user. The incoming message from SM-SC to the terminating TE shall include the CLI function.
Detailed specifications related to TE and SM-SC interworking is out of scope of the national requirements. In this situation, the SMS testing procedure contains only tests related to CLI function and the methodology of SMS testing covers part of methodology of the CLIP CW service.

7. Test procedures

Telecommunication standard bodies (ITU-T and ETSI) have not published detailed procedures for testing terminals serving FSK protocol, but ETSI has published the above mentioned documents describing general principles concerning testing process. In this situation the procedures developed at National Institute of Telecommunications, containing suitable tests, are useful and needed tools on current level of development and provision of services based on FSK protocol.
Test procedures were prepared on the base of methodology and standards concerning display and relating services, FSK protocol and testing of terminals. Tests comply with national requirements for services and FSK protocol. Test documentation consists of group of detailed tests, which extend the cases specified in document [12] and of group of additional tests not specified in this document.
In accordance with the principles specified in [12] each layer has separate testing procedures. Moreover, separated procedures in "on-hook" and "off-hook" loop state for two lower layers have been prepared. The procedure for "on-hook" state contains tests related to data transmission used in Polish network (associated and not associated with ringing). These are procedures concerning normal cases in which parameter values and sequence elements comply with requirements. These are also the exceptional procedures concerning cases with the extreme values of the parameters and with modified elements of the sequences (not complying with requirements).
Physical layer testing procedure contains tests dedicated to check the response of the terminal to receipt of Ringing Pulse Alerting Signal (RPAS), DTAS and to verify timers concerning data transmission (T_2, T_3 for idle state and T_U, T_F for busy state).
Data layer testing procedure contains tests dedicated to check the function of recognition of signals transmitted before data transmission and the message codes. This procedure allows to check the response of the terminal to receipt of correct and incorrect sequences of FSK protocol, in particular in case of the signal transmitted before data transmission is started (channel seizure signal and mark signal) and messages with incorrect codes.

Table 1
Normal procedure—subscriber line in busy state

IDENTIFIER: PHY_02_001	
TITLE: Receipt of a DTAS signal	
SUBTITLE: Receipt of a DTAS signal, return of a valid TE-ACK signal and mute voice path in T_A	
REFERENCE: ETSI ES 200 778-2 p. 4.3.2 and ETSI ES 200 778-3 PICS: MC.4	
PURPOSE: Verification of a DTAS signal recognition within T_A	
PRE-TEST CONFIGURATIONS: Subscriber line in busy state	
CONFIGURATION: Fig. 2	
EXPECTED TEST SEQUENCE: Simulator ⟷ Network terminal DTAS signal ⟶ Timer T_A ⟵ TE-ACK Timer T_A expired	
	TEST DESCRIPTION:
1	Set $T_A = 85$ ms in simulator's data base
2	Make a call (handset off-hook)
3	Send a DTAS signal with nominal values
4	Check that the terminal receiving a DTAS signal correctly, mutes the voice path and returns a valid TE-ACK signal within T_A
EXPECTED RESULTS: Correct reception of a DTAS signal Muting of the voice path	

Presentation layer testing procedure contains tests dedicated to check the function of displaying the mandatory and optional parameters concerning realization of each display service. These tests consist of:

- one or two mandatory parameters,
- one mandatory and one optional parameter,
- all mandatory and all optional parameters not excluding one another.

The above mentioned procedures give possibility to check the response of the terminal to receipt of incorrect sequences of FSK protocol, in particular the message with unknown parameter, without parameter, with two equal parameters, two parameters excluding one another and others.
Test documentation was prepared according to recommendations described in [12] but it comprises wider scope of tests than this standard and tests are also more detailed. Certain tests were modified according to the national requirements.

8. Example of the test description

Here is a sample of detailed test description included in our set procedures. Full set includes about 100 detailed test descriptions. An example of the physical level test description concerning receipt of a DTAS signal is presented in Table 1.

9. Conclusion

Testing methodology and test procedures were prepared, based on the most recent ETSI standards. This guarantees that NIT's solution is true, fair and in compliance with EC requirements. The detailed tests, developed according to the assumptions given in the methodology and in [12], allow to check wide scope of functional and electrical parameters of terminals handling "display and related services".
Physical and data layer tests (as lower layer tests, common to all services based on FSK protocol) may also be used to test another services. Based on this methodology, presentation layer test procedures may be easily extended in order to test wider group of services. This methodology may be used for testing of subscriber terminals in various phases of implementation and operation in public network.
Tests give the possibility to estimate, in wide scope, the conformity of the testing implementation to the national requirements and European standards.
Tests developed may be executed using commercially available test equipment.
It should be underlined, that elaborated tests and methodology were based on experience gained during testing of telecommunication services and other signalling systems

and any tests have not been used for testing of FSK protocol.
The methodology was presented on 19th November 2003 during AT-F Working Group meeting in Sophia Antipolis.
Methodology described in this paper will be used at National Institute of Telecommunications (NIT) in the near future in order to perform extended scope of tests in NIT's Laboratory. The Institute takes actions to include these tests into the formal testing procedures and to extend the scope of testing process.

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