ACCELERATING WIRELESS INTELLIGENT NETWORK STANDARDS THROUGH FORMAL TECHNIQUES

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Abstract – Wireless Standards such as ANSI-41 and WIN are dynamic in nature, continuously evolving to meet subscriber requirements with ever shorter intervals for standards development. The current timelines at which a new version of the specification is to be completed to the needed level of precision, quality and completeness cannot be accommodated using existing specification techniques.

A key assumption is that future standards work must apply techniques that can be automated. The use of formal documentation techniques using commercial tools will shorten the standards development cycle, introduce a formal test methodology, and assist in rapid validation and verification, harmonization, and evolution of ANSI-41/WIN standards.

This paper begins with an introduction of certain relevant documentation techniques. The techniques utilized for the creation of ANSI-41 and the Wireless Intelligent Network (WIN) standard are examined and analyzed. This is used to identify opportunities to utilize documentation techniques to enhance ANS1-41/WIN standards development from an efficacy and timeliness perspective.

The requirement to develop global capabilities and services to support third generation wireless networks provides further challenges, necessitating a fundamental change in the specification techniques used in the future.

I. INTRODUCTION

Standardization bodies such as ITU, ISO, ANSI, ETSI, and TIA are continually assessing the documentation techniques used in the development of telecommunication standards. The development of the ANSI-41 standard, which supports the functionality to sustain basic wireless capabilities such as seamless roaming and authentication, provides an example of such a standard. ANSI-41 was first published in February 1988. Since initial publication four revisions have been published to support enhanced functionality. ANSI-41 exclusively supports the messaging and protocol interfaces between MSCs and HLR/VLRs.

In 1994, based on a System Requirements Document (SRD) prepared by the Cellular Telecommunications Industry Association (CTIA), work commenced on a standard to support Wireless Intelligent Network (WIN) functionality. WIN utilized documentation techniques employed in ANSI-41 given this was the base standard. The WIN Standard was recommended for publication as IS-771 in December 1998 and is scheduled for incorporation into ANSI-4 Revision E which is scheduled for publication in the year 2000.

While the participants were satisfied with the content and technical validity of the standard, concerns were articulated over the amount of time consumed in the development cycle. These comments highlight a fundamental timeliness concern. Previously, standard development cycles of up to 4 years may have been appropriate given carrier and subscriber expectations. Timelines of this nature are no longer sustainable in the current market environment. The publication of IS-771, the WIN Standard, will result in an intelligent network services bonanza which will further propel the development of additional and enhanced WIN capabilities. Recent input from CTIA confirms this expectation. The creation of a standard to support advanced technically complex capabilities in compressed timeframes creates a formidable challenge. We believe that such challenges necessitate an axiomatic change in how standards are created, moving from an environment in which standards are developed using non-machine processable documentation techniques developed on an *ad hoc* basis, to utilization of techniques which can be machine processed and verified. The use of such documentation techniques will not only shorten standard development cycles, but also provide an opportunity that does not currently exist to test logic and protocol design during the standard development phase.

II. STANDARD DOCUMENTATION TECHNIQUES OVERVIEW

In this section, an overview of selected specification techniques is provided. It should be noted that some techniques discussed were not available when the first version of ANSI-41 was published in 1988. The specification techniques examined are:

- SDL (established, mature)
- MSC (established, mature)
- ASN.1 (established, mature)
- TTCN (established, mature)
- UCM (emerging, maturing)

Specification and Description Language (SDL)

SDL is an object-oriented, formal language defined by ITU-T as recommendation Z.100 [6]. In 1988 SDL achieved the status of a mature Formal Description Technique (FDT) [4]. The language is intended for the specification of complex, event-driven, real-time, and interactive applications involving concurrent events. The European Telecommunications Standards Institute (ETSI) has also recommended that SDL be considered as a preferred formal technique to be used for ETSI standards [4].

SDL provides graphical symbols to represent flow lines, input, output, tasks and decisions. It supports the incorporation of ASN.1 notation.

Commercial tools for the creation of SDL exist. They are constantly being upgraded by the software vendors in response to user needs. As a result, SDL has developed into a mature robust technique, interworkable with other techniques such as MSCs, and TTCN which can not only be utilized for specification documentation, but can also be machine compiled and verified to create software code such a C and C++ [12]. These tools enable higher quality standards to be written, and greatly simplify and verification process.

Message Sequence Charts (MSC)

MSC, standardized by ITU-T in 1992 in Z.120, [8] is a graphical and textual language for the description and specification of the interaction scenarios between system components. MSCs may be used for requirement specification, simulation and validation, test-case specification and documentation of real-time systems.

MSCs may be considered a technique complementary to SDL. MSCs may be used to assist in problem identification prior to the creation of an SDL model. Conversely, MSCs may also be utilized following the design of an SDL model to provide another opportunity to check the validity of such a model where complex dynamic behavior is the norm [12]. A recent enhancement supports High-level MSCs, including control structures that can combine several MSCs [1]. In addition, MSCs are supported by commercial tools which can be used to validate the likelihood of a described scenario taking place and the circumstances associated with such occurrence in a machine readable output. [12]

Abstract Syntax Notation One (ASN.1)

ASN.1 is a language for describing structured information, typically information intended to be conveyed across a communication interface. This language which originally included the ASN.1 notation and Basic Encoding Rules (BER) was standardized in 1984 by the ITU-T as recommendation X4.08 and X.409 [10].

ASN.1 is an extension of the well-known Backus-Naur Form. ASN.1 is both an ISO and ITU standard often used in combination with SDL [7]. By nature, ASN.1 is easily learned and easy to make human readable.

As is the case with SDL and MSC, ASN.1 is supported by commercial tools and can be used as standardized notation for integration into the SDL. When created through the use of commercial tools, ASN.1 can be compiled to create machine code, providing an easier path to implementation of a standard.

Tree and Tabular Combined Notation (TTCN)

TTCN was first defined in ISO IS 9646 in 1990. TTCN was created in part to address an immediate need for a test notation. A phase of TTCN development was linked to the creation of standardized test suites for protocol testing of X.25 [9].

TTCN consists of a tree notation, which is used for the description of dynamic events which can occur as a response to some earlier event, and a tabular format used for component and data type representation.

Although TTCN was not originally intended to be directly executable, since it is supported by commercial tools and can support ASN.1 notation it has evolved into a powerful machine readable format tool capable of creating software code [12]. TTCN is a premier means to create and validate a suite of abstract test cases. These test cases then can be applied to rapidly verify an implementation, and also to increase the likelihood of interoperability.

Use Case Maps (UCM)

UCM is a visual notation developed for capturing requirements of reactive systems by Carleton University (Ottawa) in 1995 [2]. UCM is an easily learned notation that can be applied to describe scenarios in terms of causal relationships between responsibilities. UCMs may be constructed to examine these causal relationships at various levels of granularity. An unbounded UCM examines tasks and relationships in isolation to where the function is performed. Conversely, a bounded UCM utilizes the same notation, mapping the functions and relationships into Functional Entities (FEs). Both unbounded and bounded UCMs utilize plug-ins to visually capture lower sub-layer activities. UCMs are viewed as particularly relevant for the first stages of the standard drafting process [2].

A sample unbounded UCM (complete with E911 and Deposit plug-ins) for a theoretical Pre-Paid Charging (PPC) capability is provided in Figure 1. (Examples of the other techniques described are not provided because they are much better known.)

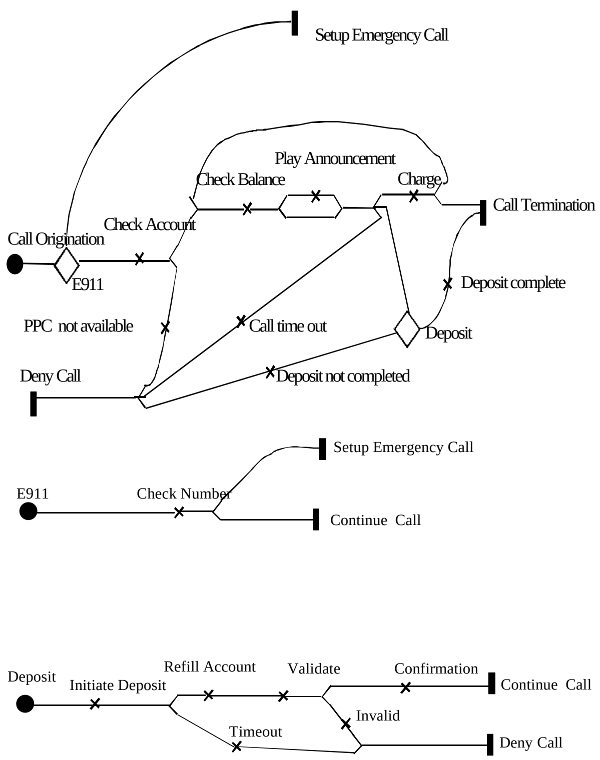

Figure 1. PPC Capability UCM

III. ANSI-41/WIN STANDARD DOCUMENTATION TECHNIQUES

In this section we review documentation techniques utilized by the ASN-41/WIN Standard before proceeding to an examination of opportunities for use of documentation techniques described above. Figure 2 illustrates the documentation phases utilized in the creation of the WIN Standard, identifying the documentation techniques utilized in each step of the process.

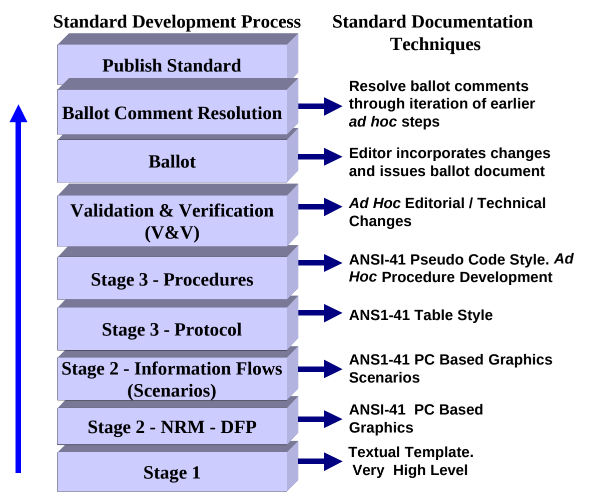

Figure 2. ANSI-41 Standard Process / Techniques

Stage 1 Capability Description

The creation of a Stage 1 description is accomplished through the use of a textual template. The intent of the template is to define a service capability and identify known service interactions. Both of these functions are performed at a very high level. Each new Stage 1 requires a revisit of all existing Stage 1s to address feature interactions.

Stage 2 Network Reference Model (NRM), Distributed Functional Plane (DFP)

The documentation of NRM and DFP models is accomplished through the use of table-based conventions and PC graphics. The ANSI-41 NRM is a mix of physical and functional views.

Stage 2 Information Flows and Scenarios

This portion of the WIN Standard utilizes an ANSI-41 table style convention with PC based signaling flow graphics used to reflect various messaging scenarios and identify parameters. Scenarios are developed on an *ad hoc* basis based on contributions submitted. No tools are utilized to define what scenarios are required or relevant. An informative annex which acts as a companion to normative protocol text incorporates ASN.1 for new WIN parameters only and is provided in a non-machine readable table format.

Stage 3 Protocol

Based on the parameters identified in Stage 2, tables using a word processing application are used to define the contents of messages and the structure and content of individual parameters.

Stage 3 Procedures

WIN Procedures utilize “pseudo-code” style narrative text to define actions and transitions. While these procedures utilize programming conventions (e.g., “ELSE” and “ENDIF”) they are strictly narrative in nature. These procedures are also developed based on an *ad hoc* contribution approach. In some cases multiple standards under development may modify an existing ANSI-41 procedure in parallel resulting in the creation of a significant editorial and rationalization challenge. An informative annex for WIN only, which acts as a companion to normative procedure text, incorporates some SDL but is in a non-machine readable format.

Validation and Verification (V&V)

This phase of WIN Standard development is commenced once the working specification is considered to be “stable.” The intent of V&V is to provide both technical and editorial corrections. Like other phases in this process, V&V is largely an *ad hoc*, contribution driven process. The V&V process takes place for a defined period but also contains an intuitive element of when V&V has been completed and a document worthy of ballot exists. No formal techniques are utilized to support development or execution of test cases.

Ballot Process / Ballot Comment Resolution

Following the completion of V&V, a ballot version of the standard is distributed and participants are requested to provide comments and submit an indication of whether they endorse the publication of the document as a standard. The Ballot process is normally defined as a 30 or 60 day period. Following completion of this step, Ballot Comments received are deliberated on their technical and editorial merits. There is no way to estimate the number of comments received or their scope. Many ballot comments address editorial errors and minor technical problems directly resulting from the unmechanized *ad hoc* techniques in use. Nor is there any way to test the impact of changes made during the comment resolution process. Following the successful resolution of all ballot comments, the standard is considered worthy of publication, but likely still contains errors and inconsistencies.

IV. ANSI-41/WIN STANDARD DOCUMENTATION TECHNIQUES APPLICATION OPPORTUNITIES

Having completed an examination of selected documentation techniques and having reviewed the current ANS1-41/WIN Standards development process, in this section we explore how these documentation techniques could be applied to enhance completeness and correctness, and shorten the development cycle of future revisions of this standard. The mapping of these techniques is provided in Figure 3.

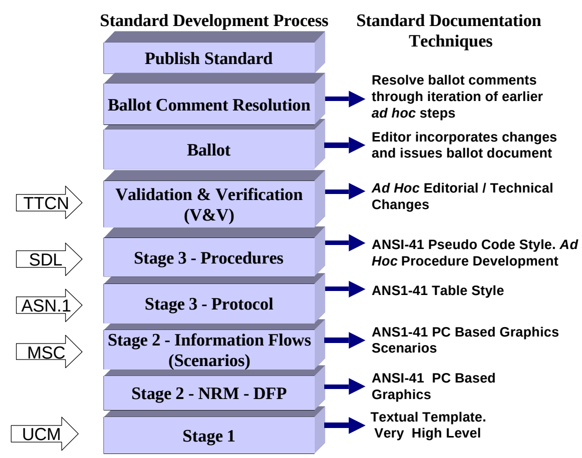

Figure 3. Placement of Additional Documentation Techniques in ANSI-41 Standard Process

Stage 1 Application of UCMs

Stage 1 descriptions would be enhanced by the application of UCMs since this notation can succinctly capture the essence of the capability proposed and provide a high level view of its capability. Stage 1 descriptions in textual format are often written in a very generic style obscuring the nature of the proposed capability. Ensuring a common understanding of a proposed capability is seen as a critical first step. While UCMs can not be verified using commercial tools, UCMs syntax and notation is easily learned and can be created using PC-based graphics software. In addition, Carleton University recently completed a UCM Navigator tool to create UCM notation. This tool may be obtained from the following Website - *http://www.sce.carleton.ca/rads/agents*/. As well, a UCM Users Group was recently created to promote additional research on this topic. Further information on this topic may be obtained from the authors of this paper.

Stage 2 Information Flows and Scenarios

MSCs can be generated using available tools. The scenarios required can quickly be identified from the paths through the Stage 1 UCMs. Experimental tools are beginning to emerge that transform sets of MSCs into formal specifications, namely in SDL.

Stage 3 Protocol

The incorporation of ASN.1 as normative text is seen as the critical first step to generation of a machine-readable standard. Use of ASN.1 for definition of parameters would facilitate the incorporation of these parameters into SDL, MSC, and TTCN, ultimately creating a capability to define procedures, generate, and execute test cases.

Stage 3 Procedures

SDL (incorporating ASN.1 notation) and MSCs using commercial tools for the development of Stage 3 Procedures would allow these procedures to be generated and tested as they are developed from Stage 2. Currently such testing capability does not exist within the ANSI-41 standards development process. The use of these documentation techniques would allow contributors to define and test their procedures prior to submission of the contribution ensuring technical validity. If revisions are required, these techniques can be employed to validate the changes. These techniques could also be used in Standards Meetings to make changes and performing testing on a "real time" basis. The use of techniques resulting in procedures based upon logic and tested using defined test suites would serve to significantly shorten the timeframes required to specify and validate procedures.

Validation and Verification (V&V)

With a draft standard written using formal techniques, a great deal of V&V will have been done already through the application of the tools. At this point in the process, a much more precise and complete draft standard will exist. The formal specification could then be run against the MSC scenarios to verify that they actually produce the MSCs desired. (At a more abstract level, the formal specification could be run against scenarios derived from UCMs.)

The use of TTCN to develop and execute test scripts provides the opportunity to test an implementation against a formally specified standard.

Documentation Technique Application Summary

Application of ASN.1, SDL, MSC, and TTCN in ANSI-41 / WIN Standards, supported by commercial tools, would result in the creation of a standard which could be rigorously tested, validated, and machine compiled prior to commencing the ballot process. This would reduce the potential number of ballot comments and significantly shorten the overall process.

V. IMPACT OF DOCUMENTATION TECHNIQUES USE ON 3RD GENERATION NETWORKS STANDARDS

Activities associated with creation and standardization of 3rd Generation Mobile Networks are underway driven by customer expectations that ultimately the wireless technology they employ will work ubiquitously. While significant discussion has been undertaken concerning 3G standards content, little activity has been undertaken to define common documentation techniques to develop these new standards. Consistent use of certain selected techniques is desirable to encourage harmonization. In general, European and Japanese Standards already significantly use documentation techniques such as SDL, MSCs, TTCN, and ASN.1 which position them well in a 3G context. While North American ANS1-41/WIN standards make some use of SDL, MSCs, and ASN.1 (but none of TTCN), more extensive use of these techniques, as ANSI-41/WIN moves forward would assist greatly in presenting ANS1-41/WIN as a robust base upon which 3G capabilities can be developed. This would also serve to eliminate perceptions that North American standards are less thorough and detailed than those of Japan and Europe [11].

Utilization of common documentation techniques running on commercial tools to develop and test the specification during the standardization process is seen as the most desirable outcome. Use of even some of these tools and techniques described would enhance the 3G standards process, through reducing the time required to do the work, improving the correctness of the results and helping promote harmonization.

VI. CONCLUSION

The use of formal documentation techniques using commercial tools for future phases of ANSI-41 and WIN Standards creation is essential. These techniques provide for more complete and precise specification, facilitate shortening the standards development cycle, and are fundamental to rapid and complete validation and verification. The introduction of a formal test methodology enables generation of machine code from the standard itself as well as test suites for validating implementations.

The use of formal techniques and tools is essential to the evolution of ANSI-41/WIN into third generation network standards.

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