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Circumnavigating SS7, Part II: TCAP Overviewp. 1

TCAP is an SS7 layer used to provide transaction management and message structuring to applications using MTP or SCCP for transport. All TCAP messages are defined recursively using a 'T,L,V' (Tag, Length, Value) format.

TIA TR-45.5/3GPP2 TSG-C CDMA Digital Air Interface Standardsp. 6

The latest status of standards for CDMA air interfaces being defined by TIA sub-committee TR-45.5 and 3GPP2 TSG-C. This does not include Wideband CDMA standards being defined by 3GPP.

Comments

We welcome comments on the format or contents of *Cellular Networking Perspectives*. We can be reached via email at:

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Glossary

For any terms you are unfamiliar with, please consult:

www.cnp-wireless.com/glossary.html

Next Issue: December 3rd, 2001

Circumnavigating SS7, Part II: TCAP Overview

TCAP (Transaction Capabilities Application Part) occupies a strange position in the SS7 protocol hierarchy. While defined as part of the SS7 family (along with MTP, SCCP and ISUP), it is implemented as an integral part of an application.

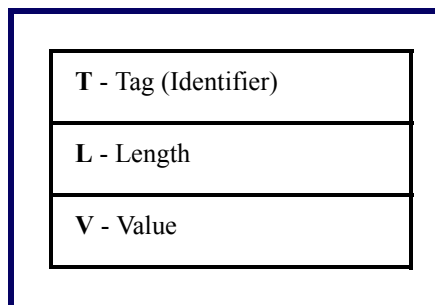
TCAP is designed for application message packaging, transaction management and, perhaps more than anything, extensibility.

We will be using examples based on ANSI T1.114 TCAP, but the basic concepts and some of the encoding apply to other variants as well.

Message Packaging

TCAP packages every parameter within an application protocol message in what is commonly known as the T,L,V (Tag, Length, Value) format:

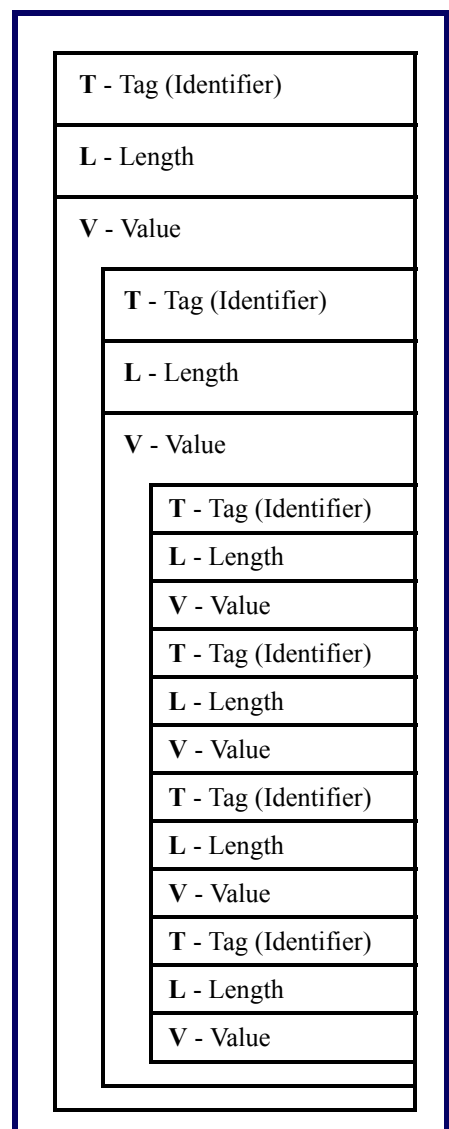
Figure 1: T,L,V Format



This format is used not only for the definition of application parameters, but also for the TCAP header, as well. In fact, a TCAP message is nothing more than a

T,L,V triplet, where the Value is itself recursively broken down into smaller elements, also of the T,L,V format:

Figure 2: Nested T,L,V Format



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Transaction Management

A transaction is simply a series of related messages between two network elements. TCAP supports transactions of almost arbitrary complexity, although most of the time, a simple command/response is used.

The role of a message within a transaction is controlled by the package type. In the most common TCAP transaction, one network element sends a 'Query with Permission' package, the recipient performs some action (such as looking up a record in a database) and then the

recipient returns the information in a 'Response' package, ending the transaction.

Table 1: TCAP Package Types

Package Type	Purpose
Unidirectional	For a transaction composed of a single message. Not desirable, because there is no way of knowing whether the message ever made it to the other end, and was processed successfully. ANSI-41, for example, no longer uses the Unidirectional package type.
Query with Permission	Initiates a transaction, and gives the recipient the right ('permission') to terminate the transaction.
Query without Permission	Initiates a transaction. Only the initiator can terminate the transaction.
Conversation with Permission	Continues a transaction, giving the recipient of this message the right to terminate the transaction.
Conversation without Permission	Continues a transaction. Only the initiator can terminate the transaction.
Response	A message that terminates a transaction.
Abort	Reports an error with a transaction (not available with earlier versions of TCAP). Also terminates the transaction.

The only other data required to manage a transaction is the Transaction Identifier. This is a 4-byte (octet) number that is assigned by one of the network elements. In simple transactions, only one is required. Complex transactions (more than two messages) may require two transaction identifiers. Unidirectional transactions do not require any.

Two transaction identifiers are required because the meaning of the number is known only by the network element that assigned it. Consequently, when a transaction is initiated by Signaling Point A (SP A) with a 'Query with Permission', a 'Conversation with Permission' response from SP B must contain the original transaction identifier to allow SP A to identify the transaction and an SP B transaction identifier to allow SP A to address subsequent messages.

Figure 3 illustrates the three basic types of transactions supported by TCAP.

ANSI-41 Revision D is a good example of the usage of package types:

- One operation (FlashRequest) was originally specified as Unidirectional, but this made it impossible for the initiator to determine whether the recipient supported this capability, which eliminated the ability to

respond to this condition. This message is now of the standard format (Query with Permission and Response).

- Inter-MS-C hard hand off involves an exchange of three messages: FacilitiesDirective (Query with Permission); Conversation with Permission (indicating that facilities for the hand off are available); and lastly, a Response message indicating the mobile has arrived on the channel in the new system.
- Interactive services (e.g. obtaining a PIN) can use the RemoteUserInteraction Directive as Conversation messages, sandwiched by another message (usually OriginationRequest) using the Query/Response format.
- The other 47 ANSI-41-D operations use the Query with Permission/Response transaction format.

Extensibility

Designers of TCAP tried hard to make it as extensible as possible. New parameters can be added to the protocol by defining new identifiers. Designers have to ensure

that operations can still be handled by the application without new parameters to ensure compatibility with older versions.

If identifiers (tags) could only be one octet long, there could not be more than 256 of them. Through an extension mechanism (see Figure 4) almost any number of unique identifiers can be defined. TCAP itself only uses one octet identifier. The need for an application to go beyond one octet to identify parameters can usually be avoided if context-specific identifiers are properly utilized (i.e. parameters are numbered separately for each operation).

TCAP lengths are usually encoded within a single octet, but to avoid limiting lengths to 256 octets, extensible lengths can also be used (see Figure 5). These are encoded in a different way than identifiers. A drawback of this method is that lengths greater than 127 must be encoded in two octets. Note that, because most SS7 networks restrict message sizes to less than 256 octets, lengths encoded in two octets (>127) are rare, and lengths encoded in 3-127 octets, while possible in TCAP, cannot be transmitted without segmentation or high speed (1.5 Mbps) SS7 transport links.

Figure 3: TCAP Transaction Types

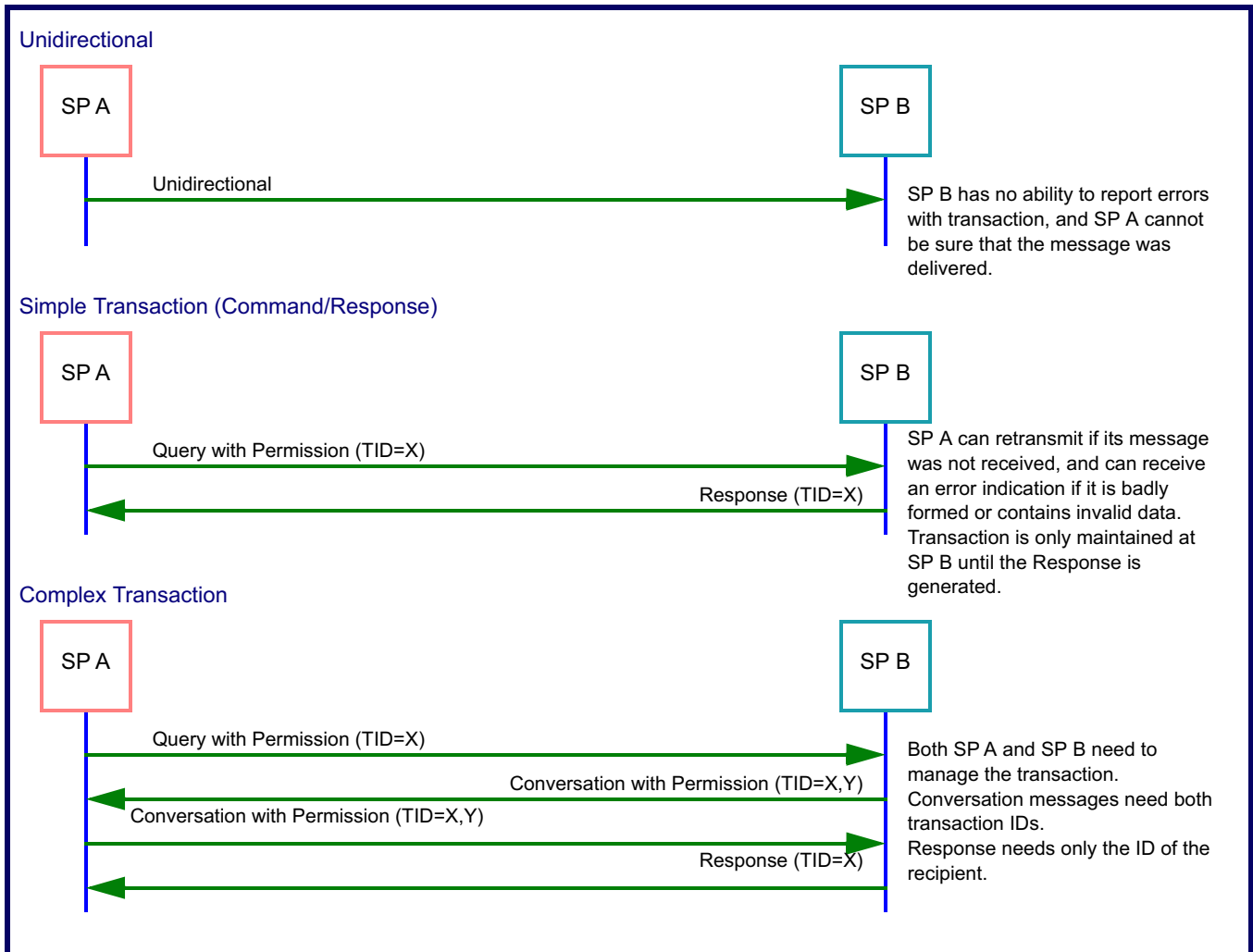
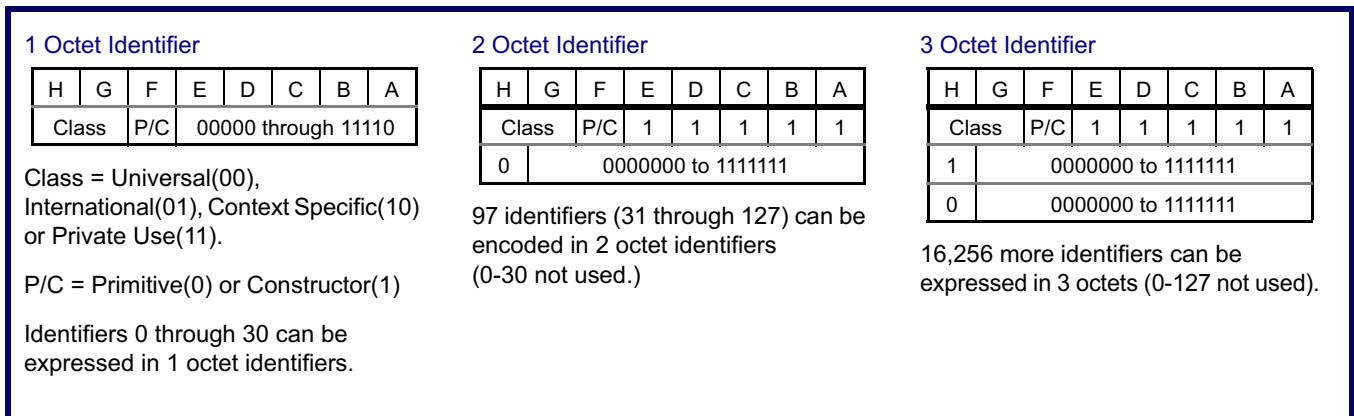


Figure 4: Extensible Identifiers



The Component Layer

TCAP messages can be structured into multiple components, theoretically allowing multiple types of information to be requested. This capability is rarely, if ever, used, as it can be implemented within an application through the use of

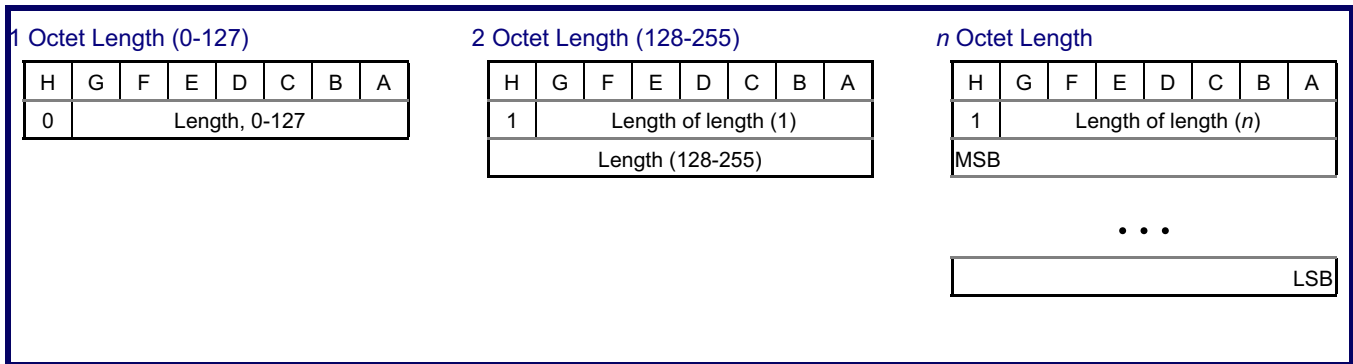
optional parameters. However, the structure of the component layer is always present, even if it adds little value.

A component is normally defined as either an Invoke that identifies an operation (see Figure 6) or a Return Result (usually a Response package). Abnormal results

may be reported, depending on their severity, by a Return Error or Reject.

Invoke and Return Result components are further identified as ‘Last’ if they are the last message in a transaction from the sender or ‘Not Last’ if they may be followed by further components. This

Figure 5: Extensible Lengths



distinction is not very useful, as the same information can be gleaned from the TCAP transaction management elements. Return Error and Reject components are always implicitly ‘Last’.

The Parameter Layer

Within a component of a TCAP package resides the list of parameters defined by the application. Parameter lists can be provided in a SET (any order) or a SEQUENCE (only to be transmitted in the order defined by the application).

Each parameter may be defined as primitive (encoded as a parameter identifier, length and simple value) or constructor (contains a value that is itself encoded in the TCAP T,L,V triplet format). Complex parameters are usually not defined strictly in the T,L,V format, because of the massive overhead that would result, particularly for parameters that can be implemented as bit fields.

TCAP Message Structure

Figure 6 illustrates the structure of a TCAP Query with Permission package containing an Invoke component. This is usually the first message in a transaction, because it both initiates the transaction and identifies the application operation.

This message, as with all TCAP messages, is structured strictly according to the T,L,V concept – several levels deep (Package, Component Sequence, Component, Parameter).

The structure of a Response/Return Result has the following differences:

- Package type is ‘Response’.
- Component type is most likely ‘Return Result (Last)’.

- Transaction ID and component identifier are ‘reflected’ from the Invoke (i.e. the same as that in the Invoke.)
- Operation Code is not included.

The structure of a Response/Error Result is similar to a Response/Return Result, but with the following differences:

- Component type is Response.
- Error Code is included (outside the parameter list, although application-specific values may be defined).
- Parameters may be included. For example, in ANSI-41 the identifier of the parameter in error may be returned.

The structure of a Response/Reject is the same as Return Error, except that:

- Problem Code is included instead of Error Code.

The Abort package type is encoded without a component, and with only:

- Package Type (Abort)
- Transaction ID (if applicable)
- P-Abort Cause, to report the type of error.
- User Abort Information, interpreted by the application, if present.

Error Handling

Errors may be generated in several ways by TCAP applications, depending on the severity. The decision of which type of error to generate is somewhat arbitrary, and applications should be as tolerant as possible when receiving error reports.

- Recoverable conditions detected by the application should be reported by a parameter within a Response package containing a Return Result component.

ANSI-41, for example, has several parameters designed to report situations where a call cannot be completed because of the status of a mobile or a network element

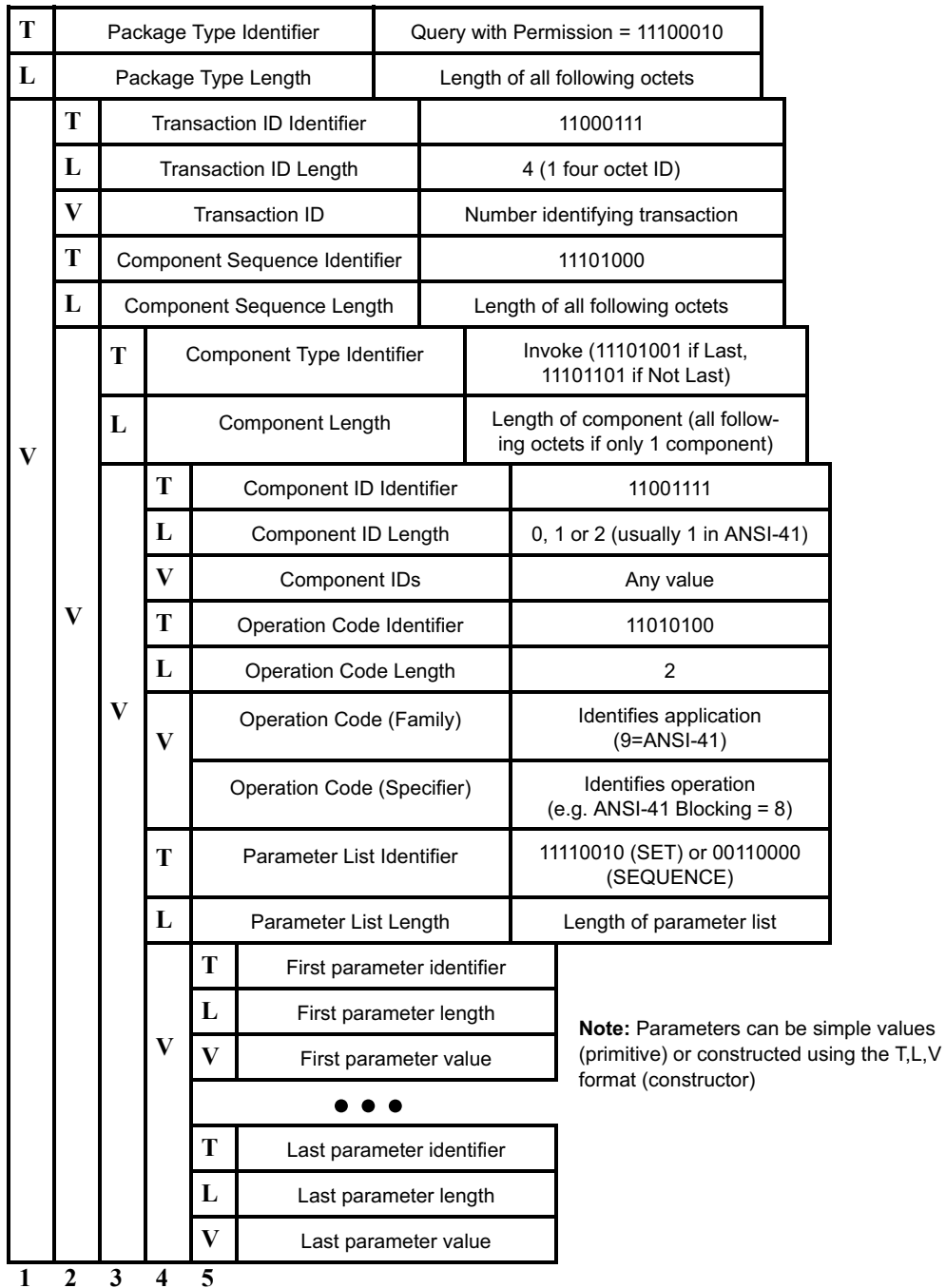
(e.g. AccessDeniedReason and AuthorizationDenied). Common situations are that a subscription does not support a request service, an invalid number has been dialed, authentication fails or a network element has not implemented the requested service.

- Application errors that do not have an application parameter designed to report them and minor encoding errors should be reported by a TCAP Response package containing a Return Error component with an appropriate Error Code (either a standard TCAP value or an application-defined value).
- Abort package type should be used for serious encoding errors. While a useful concept, this should be avoided on systems that support only earlier revisions of TCAP (e.g. the 1988 version of ANSI T1.114), or if the TCAP revision level of the network element being communicated with is unknown.
- A Response package type containing a Reject component should be used when the Abort package type is not available.

To be continued...

We will conclude our discussion of TCAP in our December, 2001 issue. We will discuss the benefits and drawbacks of TCAP, comparing it with other encoding protocols (such as XML). We will also discuss ASN.1/BER, the standard that might be used for defining protocols implemented by TCAP.

Figure 6: Query/Invoke Format (not to scale)



Nesting level. Note that, at each of the 5 levels shown, the T,L,V format is strictly followed.

TIA TR-45.5/3GPP2 TSG-C CDMA Digital Air Interface Standards

Cellular Networking Perspectives

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- Note:
1. IS- Interim Standard, TSB- Telecommunications Systems Bulletin, PN- Project Number, SP- ANSI Standards Proposal.
 2. TSG-C standards are identified as C.[P|R|S]dddd-[0|A..Z] vX.Y where P=Project, R=Report, S=Specification, dddd=Document number, 0,A..Z is the revision number (0 sometimes omitted), X is the publication number (0 for pre-publication) and Y the internal editing revision (which we omit).
 3. Published TIA standards can be obtained from Global Engineering Documents at 1-800-854-7179.
 4. **Bold Type** indicates a modification since the previous publication of this information.

Thanks to Lisa Collichio (Qualcomm) for her assistance compiling the information in this table.

First Wave - Cellular

Standard	Description	Status
IS-95	CDMA Dual-Mode Air Interface Standard (Authentication Appendix Nov. 1992)	Published 07/93
IS-96	CDMA Option 1: Voice Coder (Speech Service Option)	Published 04/94
IS-97	Base Station minimum performance standards for IS-95-A	Published 12/94
IS-98	Mobile Station (MS) minimum performance standards	Published 12/94
IS-126	Service option 2: Loopback	Published 12/94 Rescinded 04/99

Second Wave - Cellular and PCS

Standard	Description	Status
J-STD-008	IS-95 adapted for 1.8-2.0 Ghz frequency band	Published 07/96 Rescinded 11/99
J-STD-018	Mobile minimum performance standards (for J-STD-008)	Published 07/96 Rescinded 02/01
J-STD-019	Base station minimum performance standards	Published 07/96 Rescinded 02/01
IS-95-A	IS-95 Revised (Authentication Appendix "A" Nov. 1994)	Published 05/95
IS-96-A	CDMA Voice Coder	Published 05/95
IS-97-A	Base Station minimum performance standards for IS-95-A	Published 07/96
IS-98-A	Mobile minimum performance standards for IS-95-A	Published 07/96
IS-98-A-1	Additional tests for IS-95 mobile stations	Published 09/97
IS-99	Data Services (9.6 kbps Fax and Circuit Switched Data)	Published 07/95 Rescinded 10/00
IS-125	Voice coder minimum performance standards	Published 05/95 Rescinded 10/00
IS-126-A	Mobile station loopback service option	Published 07/96 Rescinded 04/99
IS-637	Short message service (rate set 1)	Published 12/95
TSB-58	Parameter value assignments	Published 12/95

Third Wave - Integrated Cellular and PCS

Standard	Project	Description	Status
TIA/EIA-95-B	SP-3693	IS-95 for 800 MHz and 1800 MHz frequencies (including J-STD-008)	Published 03/99
TIA/EIA-96-C	SP-4138	CDMA Voice Coder (8 kbps)	Published 08/98
TIA/EIA-97-B	SP-3814	Minimum performance standards for base stations	Published 08/98
TIA/EIA-97-C	SP-4384	Minimum performance standards for base stations (merges TIA/EIA-97-B and J-STD-019)	Published 09/99
TIA/EIA-98-B	SP-3815	MS minimum performance standards	Published 08/98
TIA/EIA-98-C	SP-4383	Merges TIA/EIA-98-B and J-STD-018	Published 11/99
TIA/EIA-125-A	SP-4682	Correction of errors in speech service option 1	Published 08/00
TIA/EIA-126-B	SP-4136	ANSI version of IS-126 (MS loopback option)	Published 08/98
TIA/EIA-126-C	SP-4578	Mobile Station loopback test	Published 08/00
TIA/EIA-637-A	SP-4391	Short message service (including service negotiation, 14.4 kbps transmission, PCS and TIA/EIA-95 support)	Published 09/99
IS-96-B		CDMA Voice Coder (8 kbps)	Published 07/96
IS-127		Option 3: Enhanced variable rate voice coder (EVRC)	Published 01/97
IS-127-1	PN-4146	Addendum #1 to IS-127	Published 08/98
IS-127-2		Addendum #2 to IS-127: TTY/TDD capabilities	Published 09/99
IS-127-3	PN-3292-AD3	Addendum #3 to IS-127	Published 09/01
IS-657		Packet data services (Internet, CDPD)	Published 07/96 Rescinded 10/00
IS-658	PN-4374	Data Services Interworking Function Interface (e.g. modem pool). Transferred to TR-45.4 for Revision A.	Published 07/96
IS-658-1		Extends the ability to perform interface status exchange at times other than call setup	Published 04/99
IS-683	PN-3569	Over the air activation (OTA) and service provisioning (Authentication Appendix A published 03/96)	Published 02/97
IS-683-A	PN-3889	OTA update: Roaming system selection and programming lock	Published 06/98
IS-707	PN-3676	14.4 kbps data services (including asynch. data, fax, STU-III and packet data)	Published 02/98
IS-707-A	PN-4145	Revision to IS-707 to be consistent with TIA/EIA-95 capabilities	Published 04/99
IS-718	PN-3648	Minimum performance standards for EVRC voice coder	Published 07/98
IS-733	PN-3972	Option 17: High rate CDMA voice coder (13 kbps)	Published 03/98
IS-733-1		Addendum #1 to IS-733: TTY/TDD capabilities	Published 09/99
IS-733-2	PN-3972-AD2	Addendum #2 to IS-733	Published 09/01
IS-736	PN-3973	Minimum performance specification for IS-733 (13 kbps voice coder)	Published 11/98
IS-736-A	PN-4653	Corrections to testing procedures in IS-736	Published 08/00
TSB-58-A	PN-4158	Parameter value assignments for TIA/EIA-95-B	Published 04/99
TSB-74		14.4 kbps radio link protocol and inter-band operations	Published 12/95 Rescinded 04/99
TSB-79	PN-3823	IS-637 update for 14.4 kbps SMS, service negotiation and Year 2000	Published 02/97

3G Version (cdma2000, IS-2000, 1xRTT, 1xEVDO)

Standard	Project	Description	Status
TIA/EIA-97-D		Minimum performance standards for IS-2000 base stations	Published 06/01
TIA/EIA-98-D		MS minimum performance standards	Published 06/01
TIA/EIA-99	PN-4617	9.6 kbps data service option for IS-2000	Published Rescinded 10/00
TIA/EIA-126-D	SP-4578-RV4	Mobile Station loopback test	Published 06/01
TIA/EIA-637-B	SP-4391-RV2	Short message service	Ballot 12/01
TIA/EIA-864	PN-4913	Minimum performance standards for cdma2000 high rate packet data access network	Ballot 11/01
TIA/EIA-866	PN-4916	Minimum performance for cdma2000 high rate packet data access terminal (TSG-C.P9012)	Ballot 11/01
TIA/EIA-898	PN-3-0031	Signaling conformance tests for cdma2000	Ballot 08/01
IS-683-B	SP-4742	OTA update, including preferred user zone list	Re-ballot
IS-707-A-1	PN-4541	Adds cdma2000 radio link protocol 3E support to 14.4kbps data	Published 12/99
IS-707-A-2	PN-4692	Data support for IS-2000-A	Published 03/01
IS-801	PN-4535	Position determination services (e.g. for E911 Phase II)	Published 11/99
IS-801-1	PN-4535-AD1	Addendum to position determination	Published 03/01
IS-834	PN-4707	Direct Spread Specification for CDMA on ANSI-41 (DS41) Upper Layers Air Interface	Published 03/00
IS-856	PN-4875	High Rate Packet Data Air Interface Specification (1XEV DO)	Published 11/00
IS-856-1	PN-4875-AD1	Addendum 1 to cdma2000 High Rate Packet Data Air Interface Specification (1XEV DO)	Ballot 11/01
IS-870	PN-4877	Test Data Service Option (TDSO) for cdma2000 spread spectrum systems	Published 04/01
IS-871	PN-4876	Markov Service Option (MSO) for determining frame error rates	Published 04/01
IS-889	PN-4905	Minimum Performance Specification for Text Telephone (TTY) Signal Detector and Regenerator	Ballot 05/01
IS-890	PN-0018	Test application specification for high rate packet data air interface (1XEV-DO)	Published 07/01
IS-893	PN-4575	Selectable mode voice code (speech and capacity-sensitive, formerly known as EVRC)	Ballot 07/01
IS-2000.1	PN-4427	cdma2000 Introduction and Overview	Published 08/99
IS-2000.2	PN-4428	cdma2000 Physical Layer	Published 08/99
IS-2000.3	PN-4429	cdma2000 Media Access Control (MAC) layer	Published 08/99
IS-2000.4	PN-4430	cdma2000 Signaling Layer 2 Link Access Control (LAC)	Published 08/99
IS-2000.5	PN-4431	cdma2000 Signaling Layer 3	Published 08/99
IS-2000.6	PN-4432	cdma2000 Analog Operation	Published 08/99
IS-2000.X-A	PN-4693	cdma2000 (all 6 (X=1-6) parts revised)	Published 03/00
IS-2000-A-1	PN-4698-AD1	Addendum for IS-2000-A. Revised parts 2 through 5	Published 11/00
IS-2000-0-2	PN-4698-AD2	Addendum for IS-2000. Revises all 6 parts	Published 08/01
IS-2000.X-B		cdma2000. All 6 parts being revised (X=1..6)	Development
IS-2000-A-2		Second addendum for IS-2000-A	Ballot 08/01
IS-2000-0-1	PN-4698-AD2	First addendum for IS-2000. Revises all 6 parts	Development 08/01
TIA-907	PN-3-0046	Video streaming	Development
TSB-58-B	PN-4691	Parameter value assignments for IS-2000	Published 12/99
TSB-58-C		Parameter value assignments for IS-2000-A	Published 05/00
TSB-58-D	PN-4619-RV4	Parameter value assignments for IS-2000-B	Published 05/01
TSB-2000	PN-4534	Capabilities requirements mapping for cdma2000 standards	Published 09/99

PN-4650	13k voice coder simulation (TTY/TDD update)	Ballot
PN-4651	EVRC simulation (TTY/TDD update)	Development

GSM MAP and Smart Card Support

Standard	Project	Description	Status
IS-820	PN-4690	R-UIM (Removable "Smart Card")	Published 05/00
IS-820-1	PN-4690-AD1	CDMA Removable UIM Addendum 1	Published 06/01
IS-833	PN-4706	Multi-carrier specification for CDMA systems on GSM MAP (MC-MAP) lower layers air interface	Published 03/00

TSG-C Cross-Reference

TSG-C Spec	Description	Status
C.R1000-0	Requirements Mapping for cdma2000	See TSB2000
C.R1001-0	Parameter value assignments	See TSB58-B
C.R1001-A	Parameter value assignments	See TSB58-C
C.S0007-0	Direct spread spectrum specification for spread spectrum systems on ANSI-41 (DS-41)	See IS-834
C.S0008-0	Multi-carrier specification for spread spectrum systems on GSM MAP (MC-MAP)	See IS-833
C.S0009-0	Speech service option	See TIA/EIA-96-C
C.S000X-0	cdma2000 (parts identified as C.S0001-C.S0006)	See IS-2000.X
C.S000X-1	cdma2000 Revision A	See IS-2000.X-A
C.S0010-0	Base station minimum performance	See TIA/EIA-97-C
C.S0010-A	Base station minimum performance	See TIA/EIA-97-D
C.S0011-0	Mobile station minimum performance	See TIA/EIA-98-C
C.S0011-A	Mobile station minimum performance	See TIA/EIA-98-D
C.S0012-0	Minimum performance	See TIA/EIA-125-A
C.S0013-0	MS loopback test	See TIA/EIA-126-C
C.S0013-A	MS loopback test	See TIA/EIA-126-D
C.S0014-0	Enhanced Variable Rate Voice Coder (EVRC)	See IS-127
C.S0014-0-1	EVRC addendum to remove 'bit exact'	See IS-127-1
C.S0014-0-2	EVRC addendum to add TTY/TDD symbol support	See IS-127-2
C.S0014-0-3	EVRC addendum 3	See IS-127-3
C.S0015-0	Short Message Service (SMS)	See IS-637-A
C.S0016-0	Over-the air service provisioning (OTASP)	See IS-683-A
C.S0016-A	Over-the air service provisioning (OTASP)	See IS-683-B
C.S0017-0	14.4 kbps data, without STU-III	See IS-707-A
C.S0017-0-1	Radio link protocol (RLP) modifications and additional packet data support	See IS-707-A-1
C.S0017-0-2	64kbps data, plus TTY/TDD support	See IS-707-A-2
C.S0018-0	Minimum performance for EVRC	See IS-718
C.S0019	Bit exact specification for EVRC	See IS-719
C.S0020-0	High rate (13 kbps) speech coder	See IS-733
C.S0020-0-1	TTY/TDD support for high rate speech coder	See IS-733-1
C.S0020-0-2	TTY/TDD support for high rate speech coder	See IS-733-2
C.S0021-0	Minimum performance for high rate speech coder	See IS-736-A

C.S0022-0	Location services	See IS-801
C.S0022-0-1	Location services addendum	See IS-801-1
C.S0023	Removable user identity module (R-UIM)	See IS-820
C.S0023-0-1	Removable user identity module (R-UIM)	See IS-820-1
C.S0024	High rate packet data air interface	See IS-856
C.S0024-1	High rate packet data air interface (addendum 1)	See IS-856-1
C.S0025	Markov service option (MSO) for determining frame error rates	See TIA/EIA-871
C.S0026	Test data service option (TDSO)	
C.S0028	TTY/TDD minimum performance specification	
C.S0029-0	Test application specification for high rate packet data air interface	See IS-890
C.S0030	Selectable mode voice coder	See IS-893
C.S0031-0	Signaling conformance tests	See IS-898
C.S0032	Minimum performance standards for high rate packet data network	See IS-864
C.S0033	Minimum performance standards for high rate packet data terminal	See IS-866