APPENDIX

Investigation of CDMA Air Interface and Protocols

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CONTENTS

ABSTRACT

This appendix deals with the Korean air interface standard, TTA-62, for CDMA Mobile Systems (CMS) [1]-[2]. The standard has been set up by Telecommunications Technology Association (TTA) which is a standardization organization in Korea [3]. This standard is an important specification that should be determined prior to the development of a digital cellular system. The CMS has been developed on the basis of this standard and the papers published in this special issue are the results of the CMS development. This appendix also describes the technical commonality of these papers. It covers the outline of the air interface and protocol specifications. The outline includes its major characteristics, radio protocol architecture, functionalties, and call processing. A comparison is also given between TTA-62 and IS-95 [4], a North American digital cellular standard.

I. INTRODUCTION

Ministry of Information and Communication (MIC) has adopted CDMA as the air interface radio channel access scheme in Korea to satisfy the requirements [1] for digital cellular system. The CDMA working group of radio communication subcommittee of Telecommunications Technology Association (TTA) was founded in 1991 in order to establish air interface for CDMA system. By following the standardization procedure as shown in Fig. 1, "Interim Standard for Common Air Interface for Digital Cellular in the 800 MHz band" (TTA.KO-0062, abbreviated TTA-62) was developed [3]. TTA-62 is a Korean air interface standard between Mobile Station (MS) [5] and Base Station (BS) [6]-[7], which applies to both analog and CDMA mobile telecommunication system. Air interface and protocols are important specifications that should be determined prior to the development of a digital cellular system. The CMS [1]-[2] has been designed, built, and field tested [8] to verify and authorize the TTA-62 as a digital cellular standard.

This appendix explains the major characteristics and the functions of TTA-62 standard on which the CMS related papers published in this special issue [1]-[2],[5]-[8] depend. It emphasizes on radio interfaces, protocols, and call processing. The differences between TTA-62 and IS-95, a North American digital cellular standard, are also described in this appendix.

II. MAJOR CHARACTERISTICS OF TTA-62 STANDARD

1. Scope of Standard

The scope of the requirements for the standard is established as follows:

- General requirements
  - Definition of air interface
  - System configuration
  - Radio interface method
- Technical requirements
  - MS requirements: transmitter and receiver requirements, privacy and authentication, supervision, malfunction detection, call processing and signaling formats
  - BS requirements: transmitter and receiver requirements, privacy and authentication, supervision, malfunction detection, call processing, and signaling formats
- Test Methods
- Sub-Rules.

2. Comparison with IS-95

We decided to minimize the differences between TTA-62 and IS-95 considering international compatibility, communication encryption, market, and domestic environment. TTA-62 standard has main differences from IS-95 as below :

- Structure of standard
- We have our proper procedures and algorithms for authentication and voice

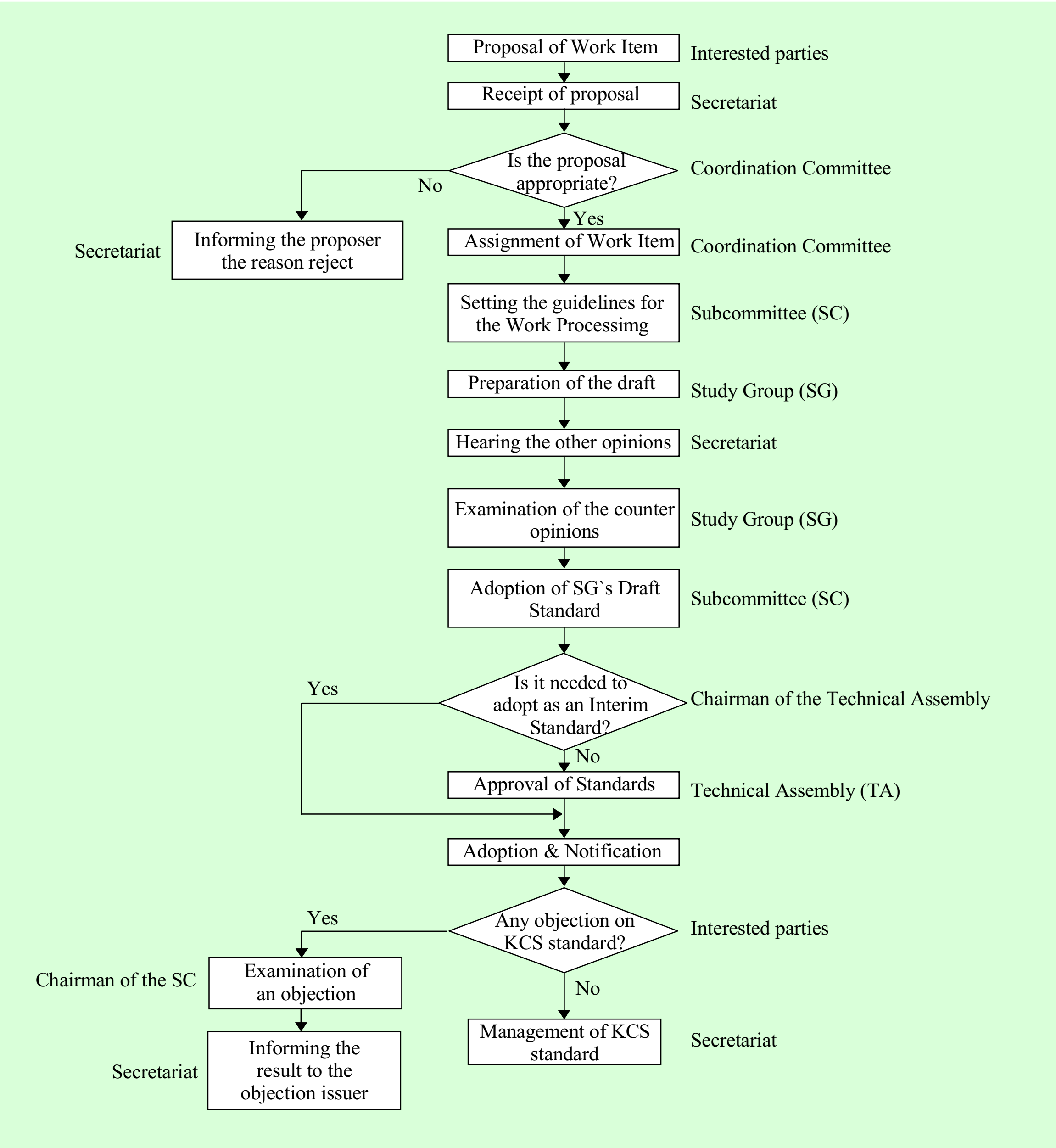

Fig. 1. Standardization procedure.

privacy [9].

- Encryption of electronic serial number (ESN) and mobile identification number (MIN) are specified as an option
- Not defined of primary and secondary channel frequency

- Analog part is specified as an option (single mode MS is possible).
- We apply to our radio management rules instead of FCC and EMI/EMC rules.

3. Features and Main Functions

Table 1 summarizes TTA-62 features.

Table 1. Features of TTA-62.

Parameter	TTA-62
Mode	Single (CDMA only) or Dual
Authentication & Voice Privacy	SAC (Subscriber Authentication Algorithm for CMS)
Duplex Method	FDD
Bandwidth	1.25 MHz
Modulation	OQPSK/QPSK
Error Control	FEC
Max. Average Subscriber Power	200 mW
Time Frame Length	20 ms
End-to-End Speech Delay	100 ms
Vocoder	Variable Rate QCELP [10]

The layer structure and its functions are shown in Table 2.

Table 2. Main functions of TTA-62.

Layer 1	- CDMA baseband modem - Frame Error Rate - Timing - Power control & randomization - Frequency selection
Multiplex Sublayer	- MUX and DEMUX of traffic channel
Layer 2	- Message build, Tx/Rx and Ack. procedure - CRC check and duplication detection
Layer 3	- Call control - Registration - Handoff - Authentication - Power control - Slotted paging and staggered frame - Message formation and decomposition

III. RADIO PROTOCOL ARCHITECTURE AND FUNCTIONALITIES

1. Architecture

Figure 2 presents the layered protocol structure of TTA-62 air interface standard based on the principles of OSI reference

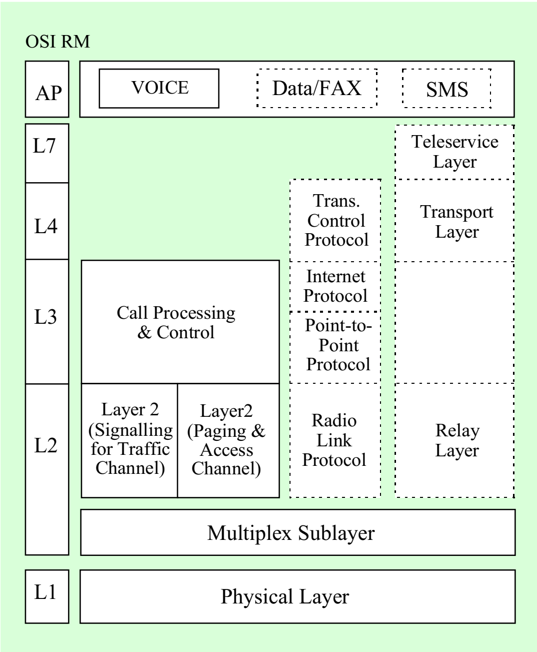

Fig. 2. Layered protocol structure of TTA-62.

model. The layering structure allows to isolate the signaling functions into groups and to describe the protocol as successive independent layers. It provides communication regularity between entities, orthogonality between functions, and clean interfaces. Thus the layering tends to make the system easier to implement. Each layer has a role of providing the upper and lower layer with its transparent service. TTA-62 recommends basically the voice service and provides room for the non-voice services such as data, G3 fax, packet data, short message service (SMS) and etc. Each service is accomplished by service option (SO) negotiation. The negotiation takes place by exchanging the desired service type information between MS and BS through the *traffic channel*. The negotiation takes the following steps: If the MS requests a SO using *origination message* or SO request order which contains the SO number, then the BS accepts or rejects using the response order. If the BS request the SO using *page message* or SO request order which contains the number, then the MS uses the *page response message* or the SO response order to reply.

The physical layer provides frame transportation for the upper layer.

The multiplex sublayer provides multiplex and demultiplex functions for the primary traffic, signaling traffic, and secondary traffic. In the sublayer, the frame format and rate decision is determined by multiplex option.

The layer 2 is modularized into *paging channel, access channel* and *traffic channel* types in order to process the signaling information efficiently.

Layer 3 has the monolithic structure for the efficient call control and short call setup delay. The non-voice service part shown by dotted lines in Fig. 2 is not yet defined.

2. Functionalities

A. Physical Layer (Layer 1)

The physical layer has the functions necessary to transfer the bit stream of data on the physical radio links. For the transmission, speech or data, after being CDMA baseband signal processed, forms a frame at the multiplex sublayer and the frame is transformed to an over-the-air waveform.

In the reception, the signal flow is reversed. Layer one offers a set of logical channels, which consists of control channel and *traffic channel*. First, the control channel is divided into four channels according to its functions: 1) The *paging channel* allows an MS to acquire the timing of the forward link, provides a phase reference for coherent demodulation, and supports a means for measuring signal strength for handoff. 2) The *synch. channel* is a unidirectional channel which transports the syncronization information from the BS to the MS. 3) the *paging channel* is a unidirectional channel from the BS to the MS which is used for transmitting the overall system information and paging. 4) The *access channel* is a unidirectional channel from the MS to the BS which is used to access a BS for call origination, page response and registration request. The *access channel* and *paging channel* is always operated as a pair to exchange the initial control messages between the MS and the BS. Second, the *traffic channel* is bidirectional which is assigned to an MS for voice and signaling information. The structure of each channel is described in [1].

B. Data Link Layer (Layer 2)

The layer 2 consists of sequence control, addressing and error control. It performs without actually establishing the data link connection. The sequence control includes acknowledgment sequence number, message sequence number, acknowledgment indicator, and valid Ack. indicator. The addressing includes the type and identifier of the MS. The error control includes the CRC field. The first two fields are positioned at the header field of the layer 3 messages, and the last field is positioned at the tail.

The layer 2 can be logically divided into two functional categories. First is the lower level-related functions such as the message formation combing message-length and CRC field, the decomposition of message into frames, detection of message start, message error control, splitting of received message, the retransmission of message and calculation of random values for random access attempts. Second is the upper level-related functions such as the address recognition on *paging channel*, an addition of address on *access channel*, sequence control using sequence numbering, acknowledgment on each channel type and the duplicate detection of message.

The acknowledgment can be accomplished either at layer 2 or layer 3 depending on the received message type. The acknowledgment at layer 2 is handled by the sequence number fields of the message. The acknowledgment at layer 3 is handled by a specific layer 3 messages. The transmitted message can be one of two types: a message requiring an acknowledgment or not requiring an acknowledgment. Most messages between mobile and BS require acknowledgment. The layer 3 acknowledgment is used when there is insufficient time during an acknowledgment cycle or when some other action implies the message acknowledgment such as in hard handoff.

C. Network Layer (Layer 3)

The layer 3 functions include the call control, handoff control and registration control over the air interface.

The call control is the main service of the layer 3 and executes a call connection for the end-to-end user communication. It allows the establishment, maintenance and release of calls and supports the call-related supplementary services such as call transfer and three-way calling. All the procedures of the call control are performed on the assigned *traffic channel* with in-band signaling scheme.

The handoff is the process to transfer the communication link of an MS from one BS to another during the call. The handoff is necessary when cell crossing or degradation of link quality occurs. TTA-62 also supports the idle handoff which occurs during the idle state of MS.

Registration is the process by which the MS notifies the BS of its location. The registration is necessary for the BS to efficiently page the MS. The MS informs the BS of its location, status, slot cycle during its idle state.

More detailed functions of layer 3 will be described in the following section.

IV. VOICE SERVICE CONTROL

1. Call Control

The call control procedures of the layer 3 can be divided into three phases: initialization, call origination and call termination.

A. Initialization

After the power is on, the MS takes the following six steps for initialization : 1) acquires the strongest *paging channel* of the BS on the CDMA primary or secondary frequency, 2) tunes to the sync channel of the selected BS and receives the sync channel message, 3) synchronizes the timing of MS to the CDMA system time which is given by the sync channel message, 4) initialize the long code state which is carried on the long code state field of the sync. channel message, 5) tunes to the assigned *paging channel*.

After the initialization, the MS monitors the *paging channel* and sets its system parameters by receiving the system overhead messages from the BS. Then, the MS is ready for a call origination or call termination.

B. Call Origination

The basic flows of call origination is shown in Fig. 3. A user can initiate a call by dialing the digits and pressing the send key. Because the MS has already got the BS information, it sends the BS an *origination message* which contains the dialed number and the SO number (for voice) on *access channel*. Then the BS acknowledges with BS Ack. order, and sends back the *channel assignment Message* which contains code channel, frame offset, frequency assignment. Then the MS receives a null traffic data on the forward *traffic channel*, and then sends a preamble for acquisition on the reverse *traffic channel*. After receiving the BS Ack. order from the BS, the MS sends a null traffic data at every 20 ms system time. In this way, the MS verifies the establishment of the forward *traffic channel* and transmit *traffic channel*.

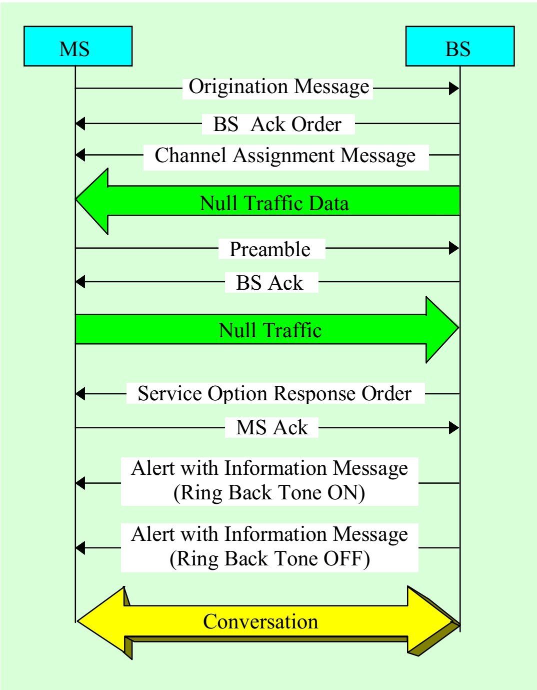

Fig. 3. Basic origination call flows over the air interface.

After that, the BS sends the SO response order to indicate rejection or acceptance of the SO requested by the *origination message*. If the SO is accepted, MS sends the MS Ack. order. Then the MS generates a ring-back tone controlled by a received *alert with information message* with ring back tone ON signal. If the called subscriber responds a call, the BS sends the *alert with information message* with tone OFF signal and the MS ends a bell. Thus the call is established. In this case, the call setup delay varies depending on the protocol transaction on the air interface and depending on implementation of call handling in the network-side.

C. Call Termination

The MS monitors the *paging channel*, which is determined by Hashing function, either in slotted mode or non-slotted mode. In the non-slotted mode, the MS always monitors all slots of the channel. But in the slotted mode, the MS watch only one or two assigned slots of 80 ms slots cycle, then goes to sleep in the other slots resulting in saving power.

The basic call flow for the MS terminated call is shown in Fig. 4. The flows of termination call is very similar to that of origination call except the addition of paging operation. The BS pages the MS by sending *page message* or *slotted page message* which contains the desired MS's MIN and voice SO number. The MS whose MIN value agrees with the MIN value in the *page message* receives the message, accomplishes the page match operation and responds by sending the *page response message*. Then the BS acknowledges with BS Ack. order, and sends a *channel assignment message* which contains code channel, frame offset and frequency assignment. The remaining procedure is the same as the corresponding procedure in the MS origination case.

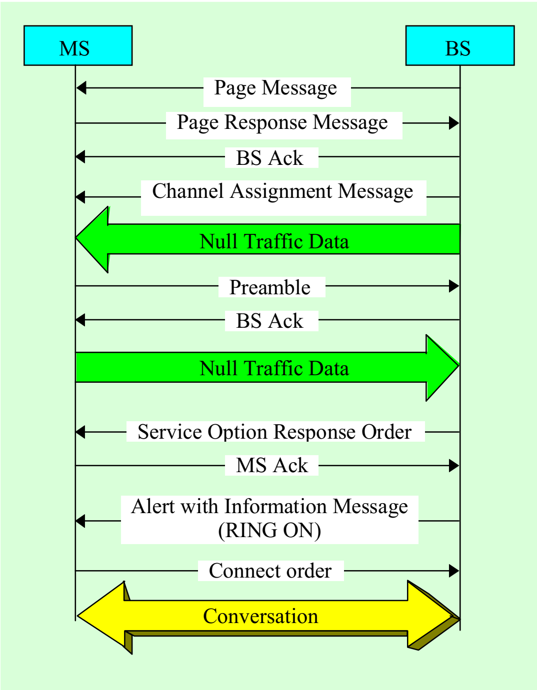

Fig. 4. Basic termination call flows over the air interface.

After that, if the MS receives the SO response order including an accepting of SO, it sends the MS Ack. order. Then the MS receives an *alert with information message* with ring tone of IS-54B signal type and sounds a bell of handset for notifying the subscriber the terminated call. If the subscriber responds the call, the MS sends a connect order to the BS. Thus the call is established.

2. Handoff Control

A. Handoff Type

The handoff scheme in TTA-62 is mainly the mobile assisted handoff in which the MS detects a pilot signal radiated by the neighboring BSs and notifies the intention of handoff to the desired BS and then the BS determines the handoff control. TTA-62 can supports the two types of handoff : soft and hard.

- *Soft handoff*: This is a make-before-break type handoff. The MS commences the communications with a new BS (target BS) without the temporary disconnection of Traffic Channel connected to the old BS (serving BS) during the handoff. Therefore soft handoff has a major which offers additional diversity, resulting in a uniform quality over the BS coverage area. For the soft handoff the assigned frequency of target BS has to be the same as that of serving BS. Most handoff in CDMA system is soft handoff.
- *Hard handoff*: This is a break-before-make type handoff. It is characterized by the temporary disconnection of Traffic Channel during the handoff. In this case, voice packet frames will be lost and lost data packets will be retransmitted after the handoff. Hard handoff can be divided into two types:

- *CDMA to CDMA hard handoff*: This handoff occurs in the case that there is not the same frequency or frame offset between two associated BSs, or the case that the MS moves to a new BS, whose BS is not maintained in the list of active set.

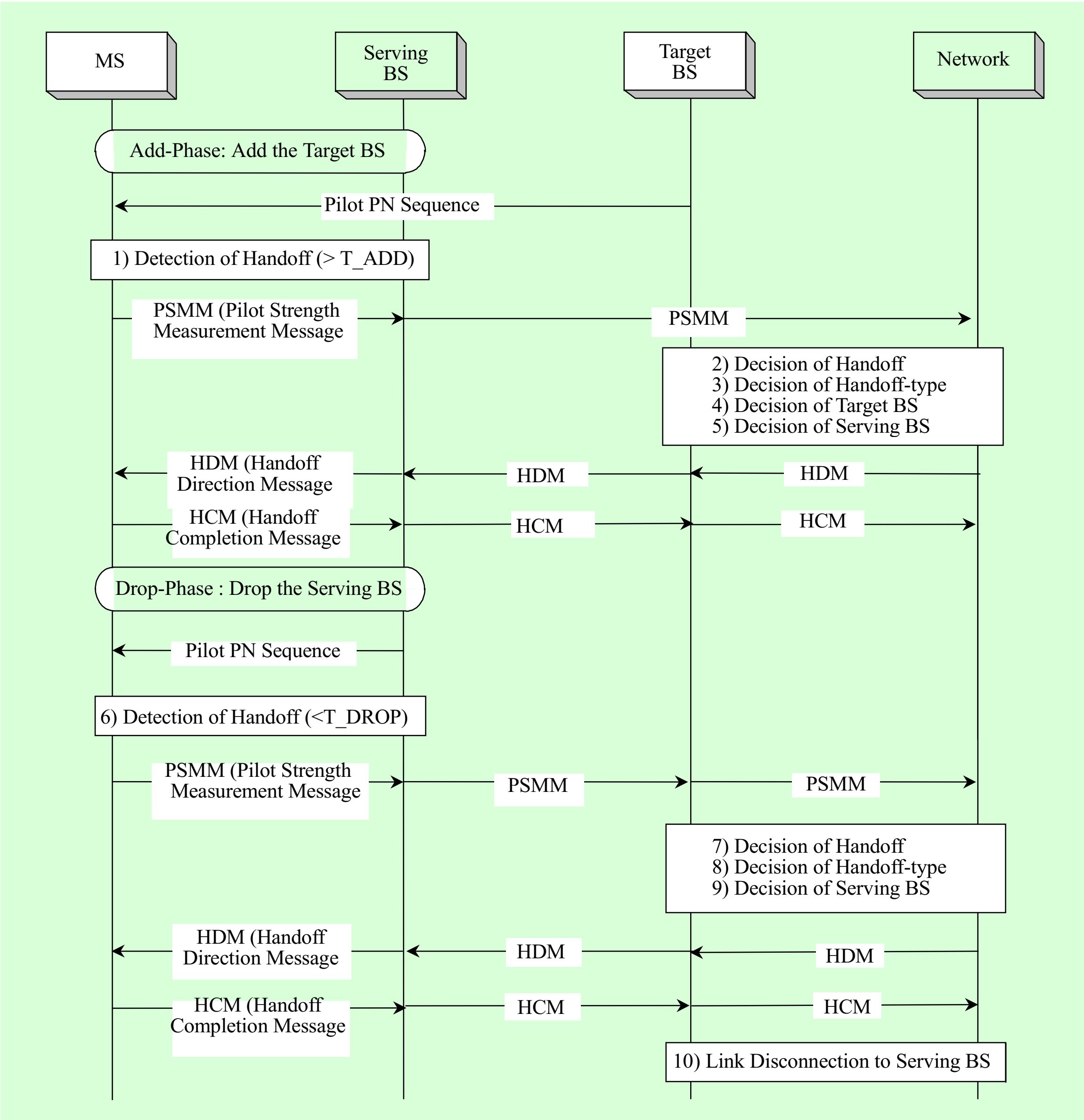

Fig. 5. Basic soft handoff flows over the air interface.

- *CDMA to analog hard handoff*: A handoff in which the MS is transitioned from a CDMA Traffic Channel to an analog voice channel.

B. Soft Handoff Operation

The typical flow of soft handoff procedure between the MS and the BS is shown in Fig. 5. Soft handoff consists of two phases : add the target BS (new cell) and drop the serving BS (old cell). In the add-phase, the MS shall continuously search for the pilot signals on the current frequency assignment from the neighboring BSs. When the MS detects a sufficiently strong pilot signal over a threshold (T_ADD), it will send the *pilot strength measurement message* to the serving BS and receive the *handoff direction message* from the BS. With this message, the MS updates the list of active set to include the detected pilot offset (target BS). The MS acquires the target BS and sends the *handoff completion message* to the network side via the serving BS.

In the drop-phase, the MS detects that the pilot strength of serving BS dropping below the threshold (T_DROP) and starts the handoff drop timer. After the timer out, the MS sends a *pilot strength measurement message to* the network side and receives the *handoff direction message* from the network side.

The MS stops the diversity combining of signals from the two BSs and continues communication with the target BS. Finally, the MS moves the pilot offset of the serving BS from the active set to the neighbor set and sends the *handoff completion message* to the network side via the target BS.

The typical handoff procedure can be summarized into the following 5 steps.

Step 1: Detection of handoff situations by MS
Step 2: Decision of handoff by network
Step 3: Preparation for handoff by network
Step 4: Performance of handoff by MS
Step 5: Completion of handoff by network

3. Mobility Control

The mobility control can support the registration of the MS location, the tracking of roaming MS location, and the updating of the subscriber profile information.

A. Registration

The registration types defined in TTA-62 are as follows:

- *Power up/down registration*: The MS registers when it turns on or turns off power.
- *Timer_based registration*: The MS registers when a timer expires.
- *Distance_based registration*: The MS registers when the distance between the current BS and the BS in which it last registered exceeds a preset distance.
- *Zone_based registration*: The MS registers when it enters into new zone.
- *Parameter_change registration*: The MS registers when certain of its stored parameters changed.
- *Ordered_registration*: The MS registers when the network operator requests registration.
- *Implicit registration*: When the MS successfully sends an *origination message* or *page response message*, the BS can infer the MS location.

- *Traffic channel registration*: When the BS has registration information for an MS that has been assigned to a *traffic channel*, the BS can notify the MS that it is registered.

The first five types are autonomous registration enabled by roaming MS. The remaining types are the special applications such as operator request and system parameter change. The network operator determines the type of registration and the frequency of registrations to be employed in the system to optimize system performance.

B. Roaming

Roamer is an MS operating in a cellular system or network other than the one from which service was subscribed. Roaming allows the foreign roamer to access service. An MS has one or more home pair [SID (system id.), NID (network id.)]. The MS is said "roaming" if the MS's current (SIDs, NIDs) pair does not agree with the visiting area (SID, NID) pair. Two types of roamer are defined in TTA-62 : foreign SID roamer and foreign NID roamer. If SIDs are different, each roamer is called foreign SID. If NIDs are different, each roamer is called foreign NID.

C. Updating of Mobile Location

The location information is maintained to locate the user for call routing in the network. The network takes and updates the location of the MS. Location updates are basically triggered by the registration request of the MS or the network. The information of MS location is primarily in the home location register (HLR). When the MS roams into other registration area, the visitor location register (VLR) requests a copy of the user service feature profile and stores the user location.

4. Authentication

The authentication is the process of confirming the identity of the MS. It's algorithms are described in subscriber authentication algorithm for CMS (SAC) document. The interface for algorithm is specified in "Interface Spec. for SAC" [9].

The authentication is accomplished by three steps. Those are a random seed confirmation, results comparison of the authentication algorithm, and confirmation of count value. The same authentication parameters – COUNT, MIN, ESN, SSD – are to be saved in both the MS and Network prior to authentication. There are basic and assistance authentication. The basic authentication includes registration, origination and termination authentication. The assistance authentication is a unique challenge response and SSD update [9].

V. CONCULDING REMARKS

This paper presented the TTA-62 air interface and protocols. It clarifies the differences between TTA-62 and IS-95. Radio protocol architecture and functionalities are discussed. TTA-62 standard is an interim standard and will be adapted regularly.

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