Abstract

This article describes network signaling for PACS (Personal Access Communications System). One of the distinguishing features of PACS is that the Advanced Intelligent Network (AIN) protocol is used, and the general AIN switch and service control point (SCP) provide the flexibility to implement PCS network/service applications. The basic method for providing PCS support transparently to the AIN switch, at least from a call processing point of view, is that PCS-related messages are sent directly from the radio system to the AIN SCP by a sort of "tunnel" through the AIN switch. The PACS design has illustrated a new approach, interconnecting the radio system with the PSTN via general AIN switches. However, extra network traffic will be created by the NCA signaling. The performance of PACS network signaling is an open issue for future investigation.

PACS Network Signaling Using AIN/ISDN

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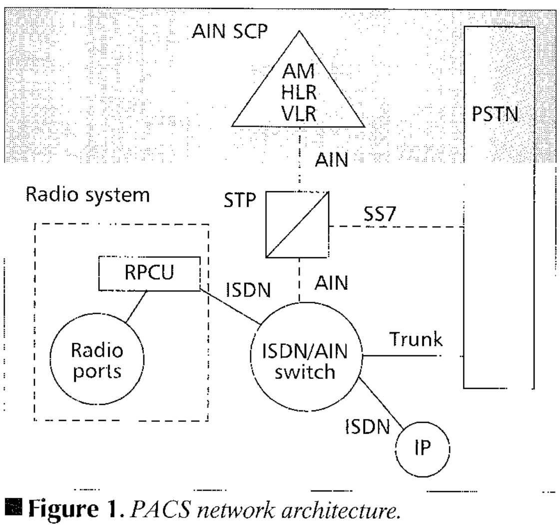
This article describes network signaling for PACS (Personal Access Communications System) [1]. PACS network signaling supports basic call control, roaming, and handoff management. The traditional cellular systems such as Advanced Mobile Phone System (AMPS) [2, 3] and Global System for Mobile Communications (GSM) [4, 5] require specific switches (i.e., the mobile switching center) and the databases to support personal communications services (PCS). One of the distinguished features of PACS is that Advanced Intelligent Network (AIN) protocol is used, and the general AIN switch and the service control point (SCP) provide the flexibility to implement PCS network/service applications. The basic method for providing PCS support transparently to the AIN switch, at least from a call processing point of view, is that PCS-related messages are sent directly from the radio system to the AIN SCP by a sort of "tunnel" through the AIN switch. In the United States, a commercial PACS system has been developed under Bellcore, Hughes Network Systems, and Siemens Stromberg-Carlson (the latter is to perform the task of system integration). The product is expected to be delivered during 1996–1997. In Taiwan, a PACS prototype has been developed by Telecommunication Laboratories, Ministry of Transportation and Communications.

Figure 1 shows the PACS network architecture. Three major elements in this architecture are the radio system, the integrated services digital network (ISDN)/AIN switch, and the visitor location register (VLR), home location register (HLR), and access manager (AM) databases. The radio system and the switch communicate via an ISDN protocol. The switch and the SCP communicate via AIN protocol. To be compatible with the existing Signaling System No. 7 (SS7) network, the AIN switch and the AIN SCP communicate with the public switched telephone network (PSTN) via SS7 protocol.



■ **Figure 1.** *PACS network architecture.*

The major design goal of PACS network signaling is to utilize the existing AIN network entities (e.g., AIN SCP and AIN service switching point, SSP) without creating new entities (such as the mobile switching center, MSC, used in other PCS systems). Basically, the PACS signaling design was motivated by the guideline that the telephony switching functions (carried out by the PSTN) should be separate from the PCS-related signaling (carried out by the PCS system). To achieve this goal, great effort has been devoted to the PACS design. Specifically:

- Non-call-associated (NCA) signaling is introduced to minimize the modifications to AIN SSP (i.e., AIN SSP does not interpret PCS-related or IS-41-like signaling messages).
- Many functions of the MSC have been moved from the SSP to the AM and radio port control unit (RPCU). In this article, AM is assumed to be collocated with the VLR; thus, some MSC functions were moved to the VLR.
- The creation of the RPCU introduces a new kind of handoff: inter-RPCU handoff. The inter-RPCU handoff procedure may simply follow the inter-BSC (base station controller) handoff procedure in GSM. However, the GSM procedure will require special functionality in the MSC. In order not to affect the AIN SSP in PACS, complicated anchor-RPCU approaches have been proposed. This article will propose a new inter-RPCU approach that utilizes general AIN SSP features.

This article provides an overview of AIN/ISDN signaling for PACS. The reader is referred to [6] for a complete treatment of PACS signaling. For PCS signaling using SS7, see [7]. A tutorial on a PACS radio system can be found in [8].

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PACS Network Elements

This section describes the PACS network elements. The details of the PACS radio system can be found in [8, 9]. The focus is on the AIN/ISDN switch and AIN SCP.

AIN/ISDN Switch

To support a PCS application, the AIN switch provides SS7, ISDN, and AIN capabilities.

The SS7 ISDN user part (ISUP) is used in the switch to set up the trunks in call control and intersystem handoff (an incomplete list of the ISUP messages appears in Table 1). The SS7 transaction capabilities application part (TCAP) is used to support mobility management (specifically, the IS-41 protocol; some IS-41 messages are listed in Table 1) and to transport AIN messages (an incomplete list of the AIN messages appears in Table 2) between the switch and the SCP.

The ISDN features are used in the switch for automatic link transfer (ALT) and NCA signaling, to be described later. An incomplete list of ISDN messages appears in Table 3. The actions taken by these messages will be elaborated on later.

Some AIN features of the switch are described below.

Triggering and Querying – Triggering is the process of identifying calls that need AIN handling. Querying is the process of assembling a TCAP message to an AIN SCP at a trigger detection point.

ISDN/AIN Interworking – NCA signaling provides a generic method for the SCP to communicate with an ISDN-connected device through the switch. The switch essentially provides an appropriate envelope for ISDN and TCAP messages. In PACS, the RPCU communicates with the VLR through this switch using NCA signaling for PCS procedures such as registration and authentication. (In the generic C scenario, SS7 provides an alternative to NCA signaling.)

Other general AIN features such as *automatic code gaping* (for traffic load control) and *automatic message accounting* (for PCS access charging) are provided for PCS applications.

AIN SCP

The AIN SCP provides the service logic, database and operation capabilities to support HLR, VLR, AM, and other PCS databases (such as an authentication center). The SCP communicates with the switch using AIN TCAP and the external PCS databases using the IS-41 protocol.

The HLR contains a PCS application process, end users' service profiles, and accounting management capabilities. HLR-to-VLR communication is done by IS-41 protocol over SS7 (some of the IS-41 messages are listed in Table 1).

The VLR mediates service requests between the HLR and the AM. The AM controls radio resources. In PACS, a handset always registers to the current VLR even if it is in the home system. In this article, it is assumed that the VLR and the AM collocate at the same SCP, and the term "VLR" represents the VLR/AM.

Name	Note
LocationRequest	TCAP (IS-41)
LocationRequest Ack	TCAP (IS-41)
RegistrationCancellation	TCAP (IS-41)
RegistrationCancellation Ack	TCAP (IS-41)
RegistrationNotification	TCAP (IS-41)
RegistrationNotification Ack	TCAP (IS-41)
RouteRequest	TCAP (IS-41)
RouteRequest Ack	TCAP (IS-41)
ACM (address complete)	ISUP
ANM (answer)	ISUP
IAM (initial address)	ISUP
REL (release)	ISUP
RLC (release complete)	ISUP

■ **Table 1.** *An incomplete list of SS7 messages.*

Intelligent Peripheral

An intelligent peripheral (IP) is a node that contains functions and resources (e.g., voice announcements or dual-tone multifrequency digit collect capabilities) needed to exchange information with an end user. The IP can be connected to a switch locally via an ISDN interface or remotely via the SS7 network. IPs may also connect to an SCP via a Transmission Control Protocol/Internet Protocol (TCP/IP) or ISDN interface. The IP does not play any major role in current PACS network signaling. It is anticipated that the IP will be used in PCS-related AIN services as proposed at the end of this article.

PACS Network Interfaces

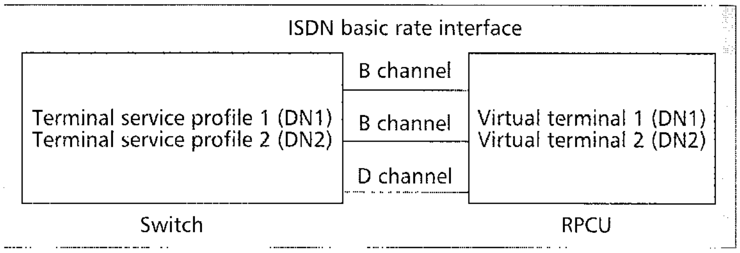
This section describes the AIN interface, ISDN interface, and AIN/ISDN interworking for the PCS application.

AIN Interface

The AIN switch and AIN SCP are like clients and servers in the remote procedure call (RPC) model [10]. During call processing, the switch may detect a need for AIN processing

Name	Note
Analyzed_Route	TCAP (response to Info_Collected)
Forward_Call	TCAP (response to Termination_Attempt)
Info_Collected	TCAP (Off_Hook_Delay trigger)
NCA_Data (P-ALERT)	TCAP
NCA_Data (P-ALERT-ACK)	TCAP
NCA_Data (P-CALL-ORIG)	TCAP
NCA_Data (P-CALLORIG-ACK)	TCAP
NCA_Data (P-DISC)	TCAP
NCA_Data (P-INFO)	TCAP
NCA_Data (P-REGNOT)	TCAP
NCA_Data (P-REGNOT-ACK)	TCAP
NCA_Data (P-RELEASE)	TCAP
NCA_Data (P-REL-COM)	TCAP
NCA_Data (RCID-ASSIGN)	TCAP
Termination_Attempt	TCAP (Termination_Attempt trigger)

■ **Table 2.** *An incomplete list of AIN messages.*



■ **Figure 2.** *The ISDN interface.*

(at the so-called *trigger detection points*). If so, one or more triggering actions are performed. Triggering is similar to invoking an RPC. The *trigger types* are like the RPC procedure names. The trigger action temporarily suspends the switch call processing, and launches a parameterized query to the SCP. The SCP performs actions based on the trigger type, and returns some results to the switch. The switch then resumes the call processing and determines the next action based on the results provided by the SCP.

ISDN Interface

Figure 2 shows the ISDN interface between the switch and the RPCU. The RPCU communicates with the switch via one or more (e.g., up to 120) ISDN basic rate interfaces (BRIs). Every BRI consists of one D channel (for signaling) and one or two B channels (for voice/data). The switch provides a terminal service profile (TSP) for every B channel connected to the RPCU. The TSP is associated with a virtual terminal (VT) in the RPCU during the terminal initialization process. Every TSP (at the switch) is assigned a directory number (DN) for PCS call origination/termination; thus, the DN is associated with one VT at the RPCU.

In ISDN signaling, every message contains a common mandatory information element called the *call reference*. The call reference is unique on a signaling interface and is used to relate the message to a particular call attempt.

The ISDN messages described in this article are listed in Table 3. The ALERT message is used to confirm the B channel selection. The CALL-PROC (call proceeding) message is sent from the called party to the calling party to indicate that the requested call establishment has been initiated and no more call establishment information will be accepted. The CONN (connection) message indicates call acceptance by the called party, and the CONN-ACK (connection acknowledgment) message indicates that the called party has been awarded the call. The REL (release) message requests the other side to clear the B connection. Upon receipt of the REL message, the receiver releases the B channel and the call reference, and then replies with a REL-COM (release complete) message. The SETUP message is sent from the calling party to the called party to initiate call establishment.

In PACS, the AIN switch may send the RPCU a FACILITY message to request permission for a handoff operation. The RPCU replies with another FACILITY message to indicate whether the handoff request has been granted. The REGISTER messages are used for NCA signaling. Depending on the information field, the REGISTER messages inform the VLR (not the AIN SSP) to carry out different operations. The details of these operations will be described later.

AIN/ISDN Interworking

With NCA signaling, the switch provides interworking functions between the SCP/VLR (AIN) and the RPCU (ISDN). NCA signaling is a unidirectional communication approach between the RPCU and the VLR, and is used for noncall control procedures (such as PCS registration and authentication). Every NCA signaling message contains necessary information to correlate a request and a response. The RPCU and the VLR keep track of the NCA signaling message exchanges. The ISDN messages exchanged between the switch and the RPCU are of type REGISTER. The operations of the REGISTER message are listed in Table 3. A standard ISDN REL-COM (release complete) message type (which is sent from the switch to the RPCU) is also used to close the ISDN transaction. The AIN messages exchanged between the switch and the VLR are of type NCAData. The operations of the NCAData message are listed in Table 3. The switch itself does not interpret the NCA messages; it only forwards the information to the destination node.

NCA signaling can be initiated by the RPCU or the VLR, as described below.

NCA Signaling Initiated by the RPCU

The RPCU initiates NCA signaling by sending an ISDN REGISTER message to the switch. The REGISTER message has a facility information element (FIE) to indicate that it is an

Name	Note
ALERT	
CALL-PROC (call proceeding)	
CONN (connect)	
CONN-ACK (connect acknowledgment)	
DISC (disconnect)	
FACILITY (ALT request)	
FACILITY (ALT permission)	
REGISTER (P-ALERT)	NCA (envelopNCAData5)
REGISTER (P-ALERT-ACK)	NCA (envelopNCAData)
REGISTER (P-CALL-ORIG)	NCA (envelopNCAData)
REGISTER (P-CALL-ORIG-ACK)	NCA (envelopNCAData5)
REGISTER (P-DISC)	NCA (envelopNCAData)
REGISTER (P-INFO)	NCA (envelopNCAData)
REGISTER (P-REGNOT)	NCA (envelopNCAData)
REGISTER (P-REGNOT-ACK)	NCA (envelopNCAData)
REGISTER (P-RELEASE)	NCA (envelopNCAData)
REGISTER (RCID-ASSIGN)	NCA (envelopNCAData5)
REL (release)	
REL-COM (release complete)	
SETUP	

■ **Table 3.** *An incomplete list of ISDN messages.*

MSG type	Invoke component of facility
REGISTER	envelopNCAData

(ISDN message)

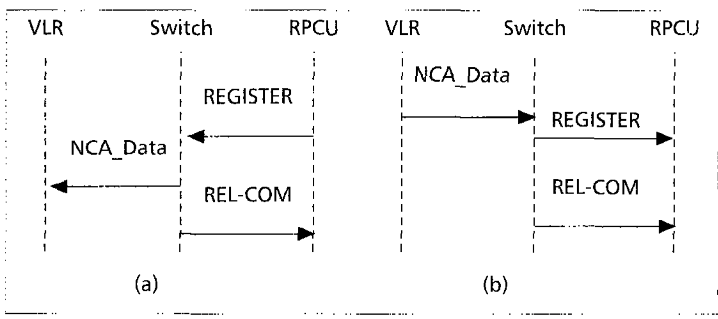
(AIN message)

MSG type	Package type	Component type	Component
NCA_data	Unidirectional	Invoke (last)	nCAData

■ **Figure 3.** *NCA message format translation (ISDN to AIN).*

Invoke type, and the operation is described in the "envelop-NCAData" component.

When the switch receives the `REGISTER` message, it forwards the information to the VLR by an AIN `NCAData` message with Unidirectional Package type. The component type of the TCAP message is Invoke as advised in the ISDN `REGISTER` message. The switch also fills the TCAP component nCAData based on envelopNCAData of the `REGISTER` message (Fig. 3). The switch does not expect any acknowledgment from the VLR. The `NCAData` message will be handled by the service logic program (SLP) in the serving SCP of the VLR. Note that the "envelopNCAData" operation of the ISDN `REGISTER` messages requires a response to indicate whether the switch has successfully forwarded the information to the VLR. An ISDN `REL-COM` message delivers the success/failure indication from the switch to the RPCU, which closes the call reference invoked by the `REGISTER` message. Note that the `COM-REL` message does not return any results corresponding to the `REGISTER` request. The message flow of NCA signaling initiated by the RPCU is illustrated in Fig. 4a.



■ **Figure 4.** *a) NCA signaling initiated by the RPCU; b) NCA signaling initiated by the VLR.*

NCA Signaling Initiated by the VLR

The VLR initiates NCA signaling by sending an AIN `NCAData` message to the switch. Based on the `NCAData` message, the switch sends an ISDN `REGISTER` message to the RPCU (the message format translation is illustrated in Fig. 5). The `REGISTER` message may be multicast to a group of RPCUs. After the `REGISTER` message, the switch also sends a `REL-COM` message without an FIE to terminate the envelopNCAData5 operation. The purpose of this message is to clear the invocation and call reference of the `REGISTER` message. Unlike the `REL-COM` message sent in the case initiated by the RPCU, this message does not provide a success/failure indication of the `REGISTER` message.

The major goal of NCA signaling is to disassociate the AIN SSP from PCS-related signaling so that when the PCS signaling protocol is modified in the future, there is no need to change the switch. To meet the goal, PACS NCA signaling is designed with the following features:

- The AIN SSP only translates the NCA signaling messages from one format to another (that is, from ISDN to AIN or from AIN to ISDN). The SSP does not interpret the messages.
- In the ISDN interface (between the AIN SSP and the RPCU), the call reference is canceled after every ISDN NCA message is issued, so the switch does not need to keep track of PCS-related messages.
- In the AIN interface (between the AIN SSP and the AIN SCP), the unidirectional TCAP message format is used instead of the general AIN transaction format (i.e., query/response TCAP format). With the query/response format, the transaction is typically associated with a timer (e.g., a HOT timer in IS-41 [9]), and a timeout period must be specified at the switch. By using the unidirectional TCAP format, no PCS-related timers are specified at the switch.

MSG type	Package type	Component type	Component
NCA_Data	Unidirectional	Invoke (last)	nCAData

(AIN message)

MSG type	Invoke component of facility
REGISTER	envelopNCAData 5

(ISDN message)

■ **Figure 5.** *NCA message format translation (AIN to ISDN).*

An alternative to NCA signaling is to have the RPCUs communicate directly with the VLR. For example, the RPCUs may be connected to the VLR by a local area network using TCP/IP. The advantage of this alternative is that the PCS-related signaling bypasses the SSP. One the other hand, the technology to connect the RPCUs and VLR must be carefully selected. For example, the local area network solution may not be scalable when the number of RPCUs is large.

Registration

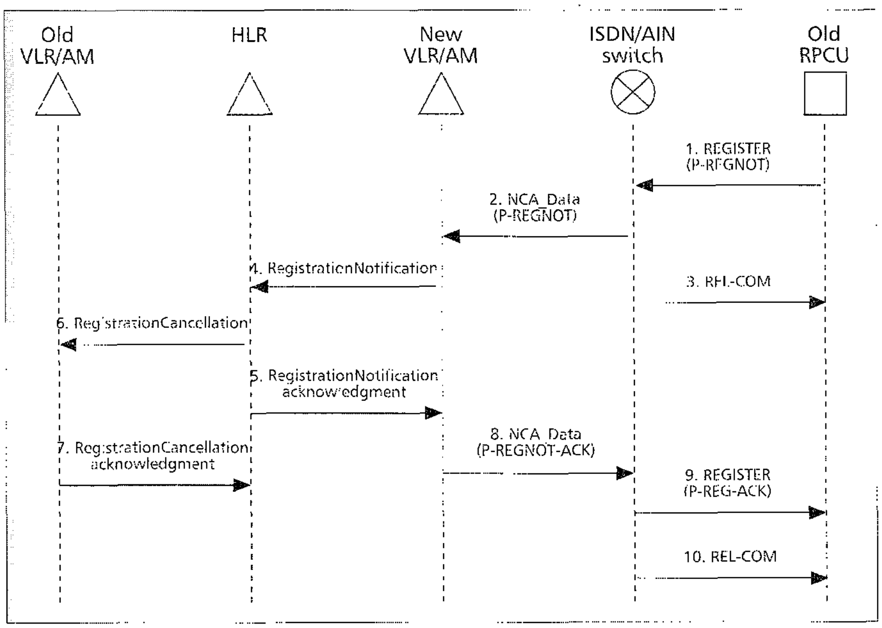
Figure 6 illustrates the PACS registration process. The RPCU communicates with the switch using the ISDN protocol, the switch communicates with the VLR using the AIN TCAP protocol, and the VLR communicates with the HLR using the IS-41 TCAP protocol. The process is described as follows:

- When a handset sends a registration request to the RPCU, information such as the location address and the authentication/security data are forwarded to the VLR (messages 1, 2, and 3) via NCA signaling. The VLR deciphers the handset identification and security. Then it authenticates the handset and performs the registration process. If the handset is in a registration area (RA) within the VLR, the HLR is not updated; otherwise, a message is sent to the HLR to be described next.
- The VLR sends an IS-41 registration notification message (message 4) to the HLR. The HLR updates the handset location record. The HLR may deny the registration, for example, if the handset has an overdue account. An acknowledgment (message 5) is sent to the VLR to indicate the completion of the HLR update process. A registration cancellation message (message 6) is sent to the old VLR to remove the resource allocated to the handset.
- The VLR informs the RPCU the completion of the registration procedure by NCA signaling (messages 8, 9, and 10). The messages may include information such as the identifier to correlate the VLR and the RPCU and the AlertID. The RPCU will pass the AlertID to the handset, which is

used in the PACS air interface for handset paging [8] .

Note that the handset is authenticated at the VLR, which is different from IS-41 Revision C, where the authentication is done at the authentication center after the HLR is accessed [11].

VLR authentication may not be an appropriate design (especially when the VLRs belong to different service providers). The current PACS VLR authentication design is due to the fact that the PACS system may interact with the existing IS-41 HLRs (which implement IS-41 Revisions A or B protocols) where the HLRs cannot interpret the authentication instruction. In the future, it will be more reasonable for PACS authentication to follow the IS-41 Revision C approach.



■ **Figure 6.** *The registration process.*

Call Origination

The following sections describe the call setup aspects of PACS call control. Call release procedures are straightforward; see [6] for details. Figure 7 illustrates the message flow for call origination. The process consists of three steps.

Step 1: Handset Authentication

When a handset requests a call origination, the RPCU selects an idle initialized virtual terminal (and therefore a B channel), and passes the call-related information (user authentication/security information, radio resource and encryption information, the selected interface DN, etc.) to the VLR via NCA signaling (messages 1, 2, and 3). The VLR authenticates the handset and returns the result to the RPCU via NCA signaling (messages 4, 5, and 6).

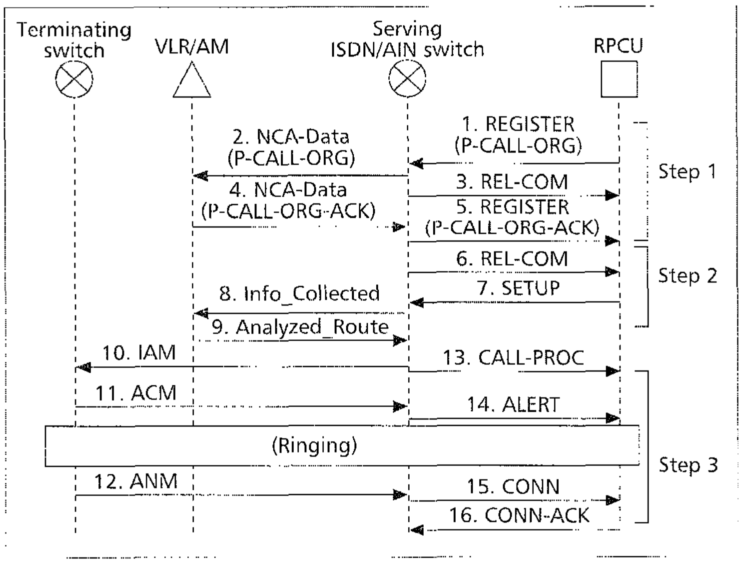
Step 2: Service Validation

The RPCU includes a progress indicator in the ISDN `SETUP` message (7) to inform the serving switch that the calling user is not ISDN. The mobile identification number (MIN) is provided in the `SETUP` message, and will not be screened by the serving switch. When the serving switch receives the `SETUP` message, it encounters the off-hook delay trigger (the trigger assignment is on a TSP basis). The AIN `InfoCollected` (8) and `AnalyzedRoute` (9) messages are exchanged between the serving switch and the VLR for service validation (e.g., to see if the calling MIN is allowed to be delivered to the called party). If the called party is a handset, the call will retrigger at the serving switch to obtain the routable address.

Step 3: Call Setup

The serving switch and the termination switch exchange the ISUP `IAM` (initial address) and `ACM` (address complete) messages (10 and 11) to set up the trunk connection. The serving switch sends an ISDN `CALL-PROC` (call proceeding) message (13) to the RPCU to indicate that the call setup is in progress. After the serving switch has received the `ACM` message, the serving switch alerts the RPCU by the ISDN `ALERT` message (14) to confirm the B channel selection. The network then provides audible ringing. After the called party answers the call, an ISUP `ANM` (answer) message is sent from the terminating switch to the serving switch, and an ISDN `CONN` (connect) message is sent from the serving switch to the RPCU (messages 12, 15, and 16), which stops audible ringing, and the conversation starts.

In this call origination procedure, the handset authentication (step 1) is separated from the service verification (step 2). Although NCA signaling at step 1 also assists in finding an ISDN BRI and an interface DN for the call setup, it would be more efficient if steps 1 and 2 are combined and NCA signaling at step 1 is eliminated.



■ **Figure 7.** *The call origination process.*

Call Termination

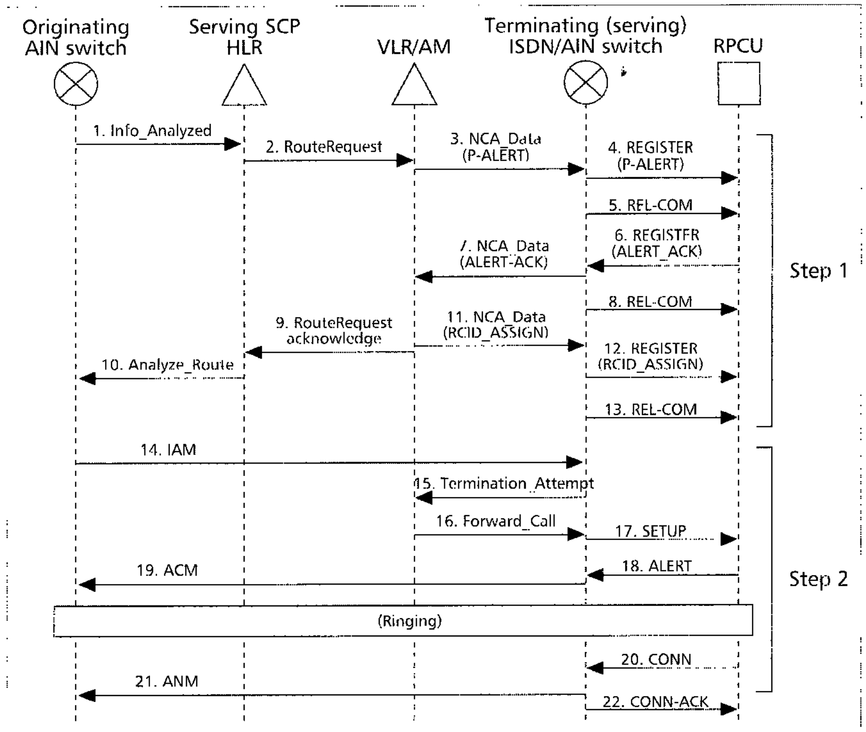
Figure 8 illustrates the call termination process. The call is originated at an AIN switch. It is assumed that the serving SCP of the originating switch collocates with the HLR (otherwise, the HLR and the serving SCP need to communicate via IS-41 `LocationRequest` messages [12]). The process consists of two steps.

Step 1

When the MIN number is dialed, the originating switch detects the `InfoAnalyzed` trigger, and an `InfoAnalyzed` message (1) is sent to the serving SCP (and thus the HLR) to query the routable address for the destination handset.

The HLR sends an IS-41 `RouteRequest` message (2) to the VLR, which sends the `P-ALERT` information to a group of RPCUs via NCA signaling (3, 4, and 5). The `AlertID` of the handset is broadcast. Once the handset replies, the corresponding RPCU selects an interface DN and an initialized virtual terminal to accommodate the call. The RPCU acknowledges the alerting action to the VLR by NCA signaling (6, 7, and 8).

After handset authentication, the VLR sends the RPCU an `RCID_ASSIGN` (radio call ID assignment) message (11, 12, and 13) to provide the session key and other information to establish the call. In parallel, the VLR sends an IS-41 TCAP `RouteRequest Acknowledgment` (9) with a routable address to the HLR. The routable address is forwarded to the originating switch (10).

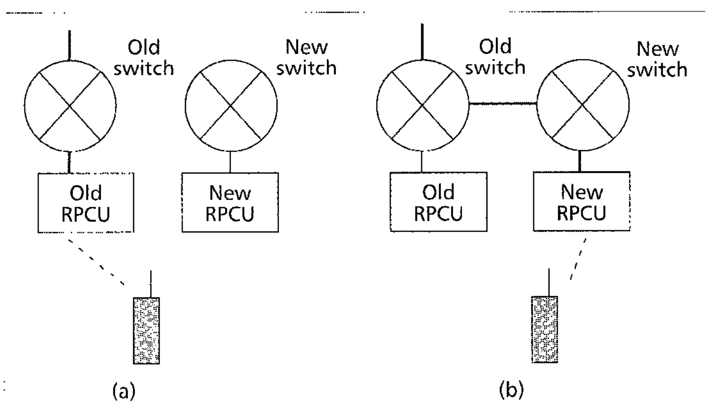


■ **Figure 8.** *The call termination process.*

Step 2

This step is similar to step 3 in the call origination procedure (Fig. 7), with two exceptions. First, the `TerminationAttempt` trigger is detected when the terminating switch receives the IAM message (14) with the routable address. Based on the routable address, the serving switch obtains the interface DN from the VLR (messages 15 and 16). An alternative to this approach is that the VLR sends the interface DN directly to the HLR (and then the originating switch) in messages 9 and 10. If so, there is no need for the `TerminationAttempt` trigger, and the exchange of messages 15 and 16 is saved. Second, after the RPCU receives the ISDN `SETUP` message (17), the handset is paged again to establish the radio link. When the handset replies, the RPCU informs the serving switch by sending an ISDN `CONN` message (20), which stops the audible ring tone.

In the PACS call termination procedure, the handset is paged twice. In IS-41 [7] or GSM [4], the handset is only paged once (at step 2) because the paging mechanism is very expensive in these systems. On the other hand, double paging in PACS is justified because the PACS air interface supports an efficient paging mechanism, and paging cost is insignificant [8, 13]. The advantage of double paging is that if the called party (the handset) is not available, the situation is detected at step 1 of Fig. 8, and step 2 is not executed to avoid the extra trunk setup overhead.



■ **Figure 9.** *Trunk connection before and after the intersystem handoff.*

Intersystem Handoff

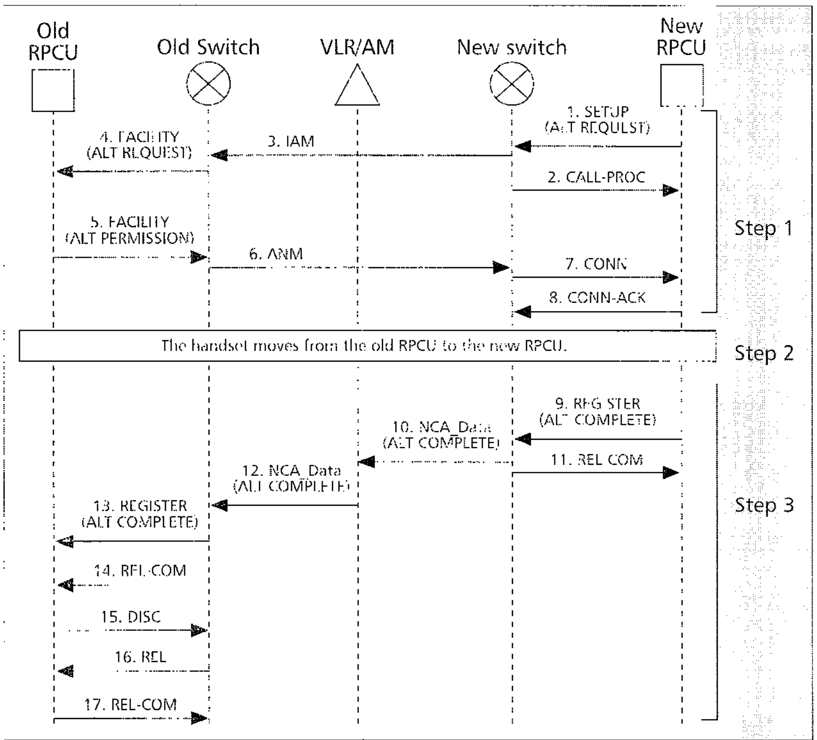
The PACS intersystem handoff or automatic link transfer (ALT) follows the IS-41 anchor switch approach . Figure 9 shows the call path before and after intersystem handoff. The inter-RPCU handoff will be described briefly at the end of this section; other PACS handoff types were described in [8]. The message flow of the PACS intersystem handoff procedure is illustrated in Fig. 10, and consists of three steps:

Step 1

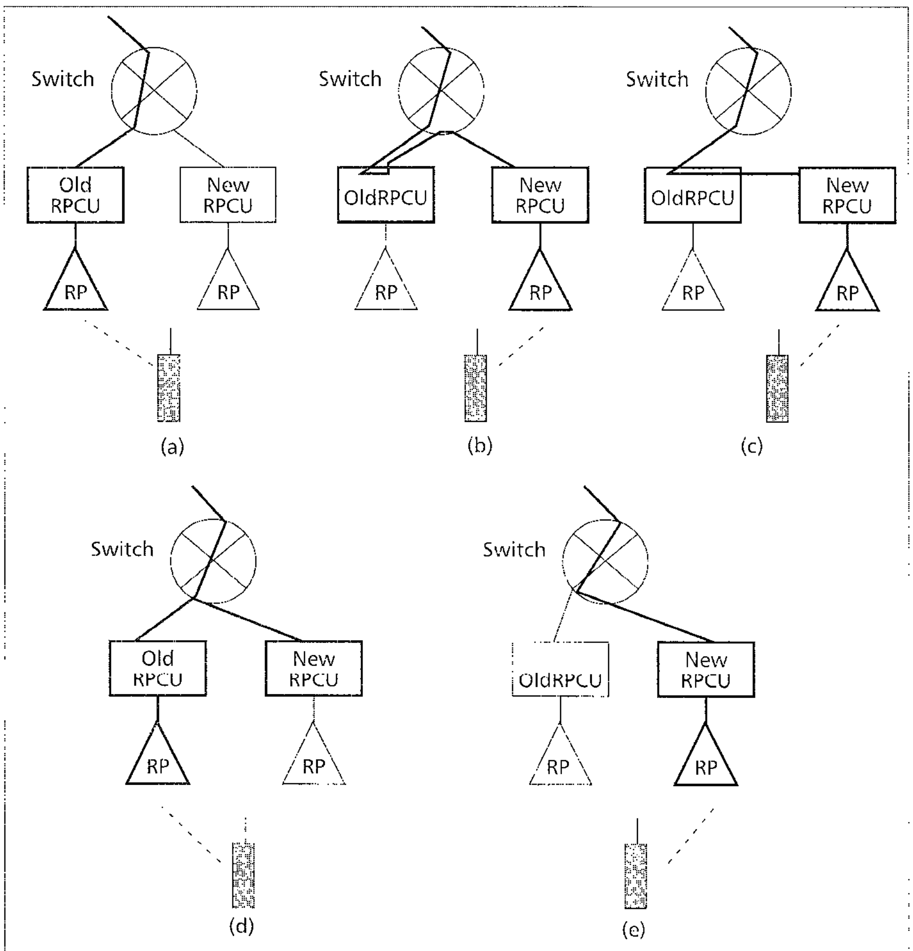
The handset sends ALT request to the new RPCU. The RPCU sends an ISDN `SETUP` message to the new switch to indicate the ALT request. Information such as the DN used by the old RPCU, and optionally the new DN and the B channel, are included in the message.

The new switch identifies the ALT request and disables the AIN `Off-HookDelay` trigger (i.e., this stage does not involve the VLR). Based on the received old DN, the serving switch determines that it is an intersystem handoff. If the ALT call is accepted, the serving switch replies with an ISDN `CALL-PROC` message (2) to the RPCU to establish the B channel connection. The new switch then sends the old switch an ISUP `IAM` message (3) to set up the trunk for the ALT request using the old DN as the called party number and the new DN as the calling party number.

From the `IAM` message the old switch identifies the ALT request. Based on the old DN (given in the `IAM` message), the old switch forwards the ALT request to the old RPCU by an ISDN `FACILITY` message (4). If the ALT request is accepted, the old RPCU sends an



■ **Figure 10.** *The intersystem ALT procedure.*



■ **Figure 11.** *Inter-RPCU handoff approaches; a) before ALT; b) after ALT (switch loopback); c) after ALT (direct connect); d) during ALT (3-way calling connection); e) after ALT (3-way calling disconnection).*

ISDN FACILITY message (5) to provide encryption and other information for the ALT.

The old switch bridges the ALT call into the original call and confirms the trunk setup (between the old and new switches) by sending an ISUP ANM message (6) to the new switch. The message also includes PCS-related information such as encryption. The new switch forwards the PCS-related information to the new RPCU by the ISDN CONN message (7). The RPCU replies with a CONN-ACK (connect acknowledgment) message (8) to the new switch to confirm the connection of the B channel.

The new RPCU asks the handset to transfer to the new radio channel.

Step 3

The new RPCU informs the VLR of ALT completion by NCA signaling (messages 9, 10, and 11). The VLR updates the handset information and informs the old RPCU of ALT completion by NCA signaling (messages 12, 13, and 14). Upon receipt of the ALT completion message, the old RPCU and old switch disconnect the B channel by exchanging the ISDN DISC/REL/REL-COM messages (15, 16, and 17).

The creation of an RPCU in the PACS architecture introduces a new kind of "intersystem handoff" called *inter-RPCU handoff* which occurs when a communicating handset moves from the RP of an RPCU to the RP of another RPCU where both the new and old RPCUs connect to the same switch.

In order to minimize the impact of inter-RPCU handoff on the AIN SSP (which is the major design goal of PACS), two anchor-RPCU handoff approaches have been proposed. In the *switch loopback* approach (Fig. 11a and b), the old RPCU dials the new RPCU to make the connection through the switch. For the AIN switch, the action is similar to an ordinary call from the old RPCU to the new RPCU. The disadvantage is that the handoff consumes two more links between the switch and the RPCUs. In the *direct connect* approach (Fig. 11a and c), the RPCUs are connected with trunks; thus, the handoff is performed without involving the switch. The disadvantage is that extra trunks are required to connect the RPCUs, and an inter-RPCU handoff protocol is required between the RPCUs. A new inter-RPCU approach is proposed as illustrated in Fig. 11a, d, and e. The idea is to utilize the existing three-way calling facility of the AIN switch. During the handoff, the old RPCU issues a three-way calling request to connect to the new RPCU (as shown in Fig. 11d). After the three-way connection is established and the handset has moved to the new RPCU, the old RPCU disconnects (for the switch, it is just like a normal one-party disconnection in a three-way calling; see Fig. 11e). This new approach only requires minor modifications to the RPCU. Unlike the anchor approaches, this approach does not consume extra trunks.

Feature Interactions

This section uses call waiting as an example to illustrate the feature interactions between the PCS application and existing telephone services. Consider the case where an ALT occurs while call waiting is active. Figure 12 shows the call path (for both active and held calls) before and after the ALT. Before the ALT, the old RPCU is the call waiting controller; after, the new RPCU is the call waiting controller. Both active and held calls are connected to the old switch after the ALT. The new RPCU will control the old switch (via the new switch) to perform call waiting commands requested by the handset.

In PACS, the ALT has precedence over call waiting. Thus, during the ALT the RPCU may either delay the call waiting commands from the handset or reject these commands.

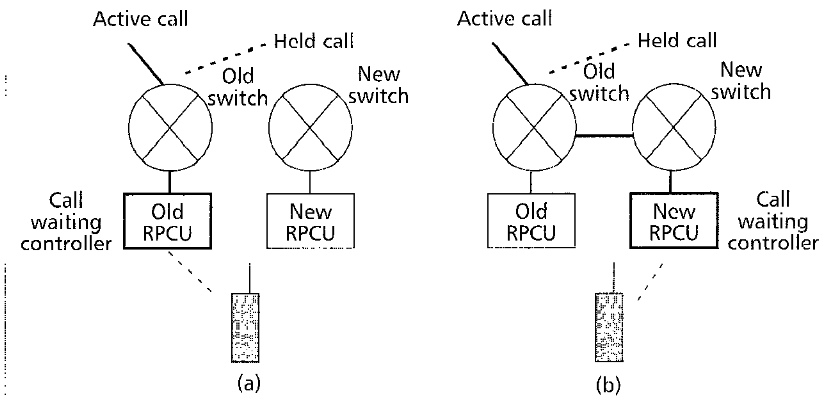


Figure 12. *ALT during call waiting.*

AIN Services for PCS

This section describes two potential AIN services for PACS (and any PCS system using IN protocols).

Fraud Protection

In high traffic areas such as New York City, fraud usage of mobile phone services is a serious problem. One may use a computer to emulate a base station and send a signal out to cellular phones to request these phones to transmit their serial numbers. These numbers can help thieves make calls and charge them to the owners of the phones [14]. To protect from fraud usage, a PCS user may subscribe to a security card with a dynamic PIN (personal identification number) where the PIN value changes from time to time. The fraud protection procedure is demonstrated in Fig. 13 and described in the following steps.

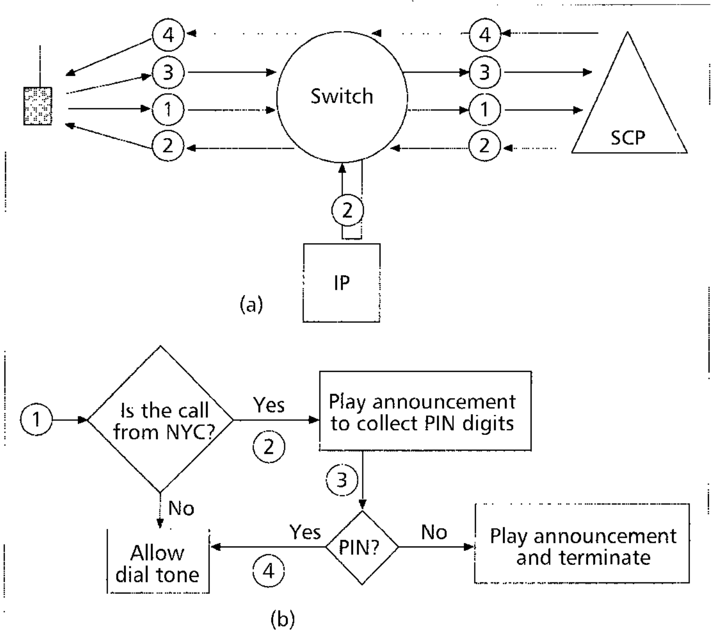


Figure 13. *Fraud protection using AIN: a) the message flow; b) service logic program in the SCP.*

- When a customer makes a call, the AIN switch sends a query to the AIN SCP. Based on the trigger type and the parameters of the message, the query is processed by the corresponding service logic program (SLP) in the AIN SCP. The SLP checks if the call is from New York City. If not, the AIN SCP instructs the switch to provide a dial tone to the mobile phone and allow the initiation of the call.
- If the call is from New York City, the SCP instructs the switch to collect the PIN number. The switch sends a message to the IP to play a voice announcement, "Please provide your PIN number," to the mobile user.
- The PIN number is collected and forwarded to the SCP.
- The SCP checks if the PIN matches. If so, the AIN SCP instructs the switch to provide a dial tone to the mobile user and allow initiation of the call; otherwise, the IP is instructed to make a voice announcement to deny the call.

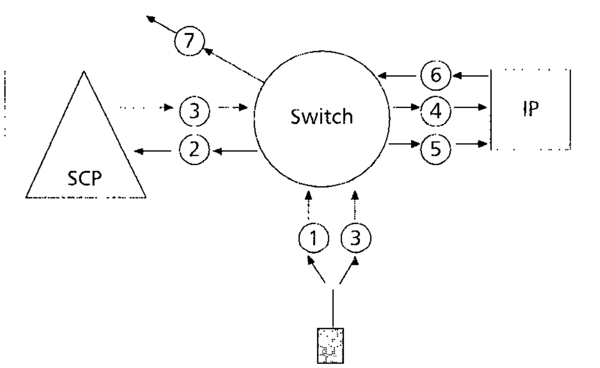


Figure 14. *Voice-activated dialing.*

Voice-Activated Dialing

Another example of using AIN is voice-activated dialing (VAD). When driving, it is inconvenient for the PCS user to dial the mobile phone. With the VAD service, the user can make a phone call by voice instruction without physical dialing. The VAD service works as follows (Fig. 14):

- The mobile user originates a call by going off-hook.
- The switch recognizes that AIN processing is required, suspends call processing, and sends a message to the SCP.

- The SCP detects the need for VAD, and sends an instruction to the switch.
- The switch signals the IP and sets up a voice path between the IP and the mobile user.
- The mobile user then speaks a name.
- The IP identifies that the name matches, and returns a routable address or directory number (DN) to the switch.
- The switch routes the call based on the directory number.

Conclusions

This article describes networking signaling for PACS which supports basic call control, roaming, and handoff management. One of the distinguishing features of PACS is that the AIN protocol is used, and the general AIN switch and SCP provide the flexibility to implement PCS network/service applications. The PACS radio system connects to a general AIN switch instead of the specific MSCs used in other cellular systems such as AMPS and GSM. In the PACS design, involvement of the AIN switch in most PCS-related features has been minimized. For example, PCS-related messages are sent directly from the RPCU to the AIN SCP by a sort of "tunnel" through the AIN switch. It is apparent that features such as call setup/release and intersystem handoff must be built in the AIN switches that support PCS. In PACS, these features are implemented without modifying the platform of the AIN switch.

The PACS design has illustrated a new approach to interconnecting the radio system with the PSTN via general AIN switches. However, extra network traffic will be created by NCA signaling. The performance of PACS network signaling is an open issue for future investigation.

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