

Abstract

A handover is required in wireless personal communications systems when a portable moves from one base station coverage area to another during the course of a conversation. In general, the handover should be completed while the portable is in the overlap region to be successful. This article considers several issues for handover management, handover detection, channel assignment, and radio link transfer.

Handover Management for a PCS Network

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In a personal communications services (PCS) system, it is important to support services when a subscriber moves from the coverage area of one base station to that of another. This process is referred to as *small-scale mobility management* or *handover management*. To illustrate the handover behavior, let us consider an example in Fig. 1. This figure shows three radio base stations and their coverage areas (or cells). Even though cellular base station towers are shown, this discussion is general and applies to both high-tier cellular systems and low-tier pedestrian systems, and to both indoor and outdoor environments. A *mobile phone* or *portable* (represented by a vehicle in the figure) is shown traversing these areas. Coverage areas are irregular because of buildings, trees, mountains, and other terrain features, and sometimes they may considerably overlap. A handover is required in mobile or portable communications systems when a portable moves from one base station coverage area to another during the course of a conversation. In general, the handover should be completed while the portable is in the overlap region to be successful. As a portable is moved toward the edge of coverage of a base station, the signal strength and quality begin to deteriorate. At some point the signal from a neighbor base station becomes stronger. Additionally, the second base station receives a stronger signal from the portable than that received by the original base station. At some point the conversation needs to be handed over to the second base station before the link between the first base station and the portable becomes unusable and the call is lost.

Several issues need to be considered for handover management.

Handover Detection

To initiate a handover, two issues must be considered:

- Who initiates the handover process?
- How is the need for handover detected?

The decision on when to effect the handover must be based on measurements of the links made at the portable or at the two base stations, or both.

While it is obvious that the measurements can be made at either the portable or the base stations, not so obvious is that the decision to effect the handover can be made by either the network or the portable. We will describe three strategies for handover detection.

Handovers are expensive to execute, so needless handovers should be avoided. If the handover criteria are not chosen appropriately, then, in the overlapping region between the two base station coverage area boundaries, the call might be handed back and forth several times between them. If the criteria are too conservative, the call might be lost before the handover can take place. The handover decision-making criteria become even more critical with the evolution to smaller cell sizes, which is being done to increase the capacity of systems and to reduce the power requirements of portable terminals. Unreliable and inefficient handover procedures will reduce the quality and reliability of the system. The propagation environment is dynamic and, even very close to the original base station, the received signal at the portable could temporarily fade due to multipath propagation so that the signal from another base station might appear stronger for a brief period. During such brief fades it is not desirable to effect a handover since it would only be a temporary fix, and indeed the signal might return to normal much faster than the handover can be implemented. We will discuss several strategies that have been proposed to address these problems.

Channel Assignment

A channel assignment scheme must trade off the following performance objectives:

- Quality of service
- Implementation complexity of the channel assignment algorithm
- Number of database lookups
- Spectrum utilization

The objective of a channel assignment strategy should be to achieve a high degree of spectrum utilization for a given grade of service with the least number of database lookups and the simplest algorithm employed in both the portable and the network.

Handover requests and initial access requests will compete for radio resources. At a busy base station, call attempts which fail because there are no available channels are called *blocked calls*. Handover requests for existing calls which must be turned down because there are no available channels are called *forced terminations*. It is generally believed that forced terminations are less desirable than blocked call attempts. Several channel assignment strategies have been developed

which attempt to reduce forced terminations at the cost of increasing the number of lost or blocked calls. Several handover-initial access channel assignment schemes, such as the *nonprioritized scheme*, *reserved channel scheme*, *queuing priority scheme*, and *subrating scheme*, have been proposed. The reader is referred to for more details. Note that handover access success is intimately tied to the radio technology of the channel assignment process, which may be dynamic channel assignment (DCA), fixed channel assignment (FCA), quasi-static autonomous frequency assignment (QSAFA), or some other fixed, flexible, or dynamic process.

Radio Link Transfer

There are two classes of link transfer procedures. For *hard handover*, the portable can only converse with one base station at a time, and there is usually some small gap in the conversation during the link transition. For *soft handover* [22], the portable can receive the signals from both base stations simultaneously and both base stations can receive the portable. The network must combine the signals from the two base stations in some way. Soft handover, which is the more complicated of the two, is required of some code-division multiple access (CDMA) systems [12] because of the near/far problem and the need for precise power control. As can be appreciated from Fig. 1, some calls will be in soft handover mode to more than two base stations. This article will focus on hard handover under time-division MA (TDMA) or frequency-division MA (FDMA) systems.

Two operations must take place for a successful handover:

- The air interface link must move from one base station to another.
- The network must bridge the second base station link into the existing call and drop the link to the first base station.

We will discuss both operations.

Link transfer can be made from one channel to another on the same base station, or from one base station to another, both of which subtend the same controller or switch. In this case the "network" operation is relatively simple. Alternatively, the handover can take place between base stations whose common point is much higher in the switching hierarchy of the network, in which case the network operation can be expensive, time-consuming, and difficult.

We will provide detailed discussions and overviews of these handover issues.

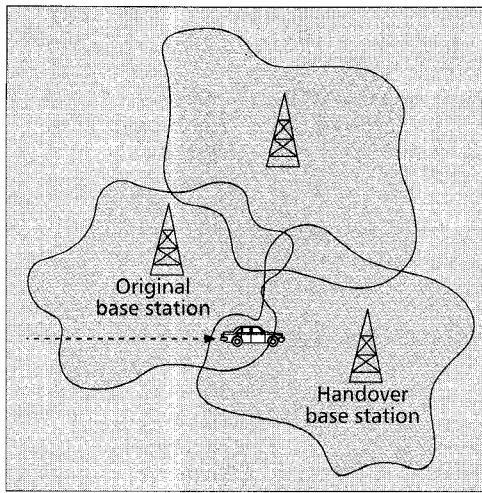
Handover Detection

This section describes link measurement techniques to detect the need for handover, and discusses three strategies to initiate the handover process.

Radio Link Measurement

Handover detection is based on the link measurement process. The measurement process determines the need for handover and the target or new channel for transfer. Three measurements are used to determine the quality of a channel:

- WEI, or *word error indicator*, is an indication of whether the current burst was demodulated properly in the portable.
- RSSI, or *received signal strength indication*, is a measure of co-channel interference power and noise. The RSSI metric



■ Figure 1. Handover.

has a large useful dynamic range (typically between 80 to 100 dB).

- QI, or *quality indicator*, is the estimate of the "eye opening" of a radio signal, which relates to the signal-to-interference (S/I) plus noise ratio, including the effects of dispersion. QI has a narrow range (relating to the range of S/I from 5 dB to perhaps 25 dB).

Handover may depend more reliably on WEI (a compilation of the measured data for the desired signal over a period of time) of the current channel rather than RSSI (i.e., if WEI is good, handover is not performed). However, it is required to accumulate WEI measurements over a period of time, whereas RSSI is

known instantaneously. To make the handover decision accurately and quickly, it is desirable to use both WEI and RSSI for the decision algorithm.

RSSI measurements are affected by distance-dependent fading, lognormal or shadow fading, and Rayleigh or multipath fading. Ideally, the handover decision should be based on distance-dependent fading and, to some extent, on shadow fading, and should be independent of Rayleigh fading. This can be accomplished by averaging the received signal strength for a sufficient period of time. The problem is that besides transmitting and receiving the desired signals for the communication link, the portable must also measure or sample all frequencies in the band of interest to find a suitable candidate for handover. Consider the TDMA system. Depending on the radio system's TDMA frame structure and duration, it may take 100–500 ms to measure all of the possible frequency channels. Maintaining a short list of the best candidate channels is a reasonable alternative since the number and frequency of measurements of the most likely candidate base stations can be increased. Therefore, the decision will need to be based on a sum of instantaneous power measurements rather than a continuous measurement, which can thus average out the Rayleigh fading.

Channel comparisons for handover are based on the RSSI and QI metrics. Since the multipath environment tends to make the RSSI and QI metrics vary widely in the short term, and since it is preferable not to perform handover to mitigate brief multipath fades (because these fades are nonreciprocal, and such handovers could cause unnecessary load on the network), the portable should average or filter these measurements before using them to make decisions.

The speed of the measurement process is dependent on the TDMA frame structure of the radio system. This capability can be used to visit each frequency channel in turn. The measurements obtained in this process are used to maintain an ordered list of channels as candidates for handover. The PACS radio system, for example, has a frame duration of 2.5 ms. For a system with 25 frequency channels, this corresponds to visiting each channel every 62.5 ms. A user moving at 1 m/s travels around 1/3 wavelength at 2 GHz in this time. If antenna diversity is employed in the radio system at the portable, the greater of the two values would be selected and the remaining measurement discarded.

Filtering should be applied to both RSSI and QI measurements. At least two methods of filtering are possible: *window averaging* and *leaky-bucket integration*.

- For window averaging, the portable maintains a number which is proportional to the average of the current mea-

measurements and the last $w - 1$ measurements, where w is the window size. To implement this, the portable performs the following procedure for each new measurement:

$$s_k = s_{k-1} + m_k - m_{k-w},$$

where s_k refers to the sum at time k , and m_k to the measurement made at time period k . Note that the portable must maintain a record of the current sample and the previous samples.

- For leaky-bucket integration, the portable implements a discrete digital one-pole low-pass filter:

$$s_k = a s_{k-1} + m_k,$$

where $a < 1$ is a constant "forgetting factor."

Either method is acceptable from a performance perspective.

Note that handover should be initiated whenever the best channel has filtered RSSI (i.e., the "stable" RSSI value measured based on the techniques just mentioned) exceeding that of the current channel by some hysteresis value on the order of 6 dB.

A filtering process applied to the RSSI and QI metrics will reduce their usefulness in mitigating sudden (shadow) fades, for example, due to rounding a corner or slamming a door. The downlink WEI can be used to detect and correct these "trouble" situations on an "override" basis. A count C_{down} is kept of the number of downlink word errors (the count is reset every complete measurement cycle). If C_{down} exceeds some threshold, the portable should initiate a handover if an appropriate channel can be found. Channel selection can follow the same process as given above; however, the hysteresis value can be lowered.

In order to reduce the potential tendency of a portable in certain circumstances to request a large number of handovers in quick succession, there should be a "dwell" timer, which keeps the portable from requesting a handover until some reasonable period of time after a successful handover. Reference [20] discusses using the Doppler frequency to estimate the velocity of the vehicle and then the measurement averaging interval to average out both multipath and shadow fading. It thus affects handover only on the basis of path loss.

The propagation between the base station and the portable is made up of the direct line-of-sight (LOS) path and also scattering paths caused by reflections from or diffraction around buildings and terrain. Thus the signal received by the portable at any point consists of a large number of generally horizontally traveling uniform plane waves whose amplitudes, phases, and angles of arrival relative to the direction of motion are random. These plane waves interfere and produce a varying field strength pattern with minima and maxima spaced on the order of a quarter-wavelength apart. The portable's received signal fades rapidly and deeply as it moves through this interference pattern. By reciprocity, the base station receiver experiences the same phenomena as the portable due to the portable's motion. The envelope process of this fast fading phenomena is Rayleigh distributed if there is no strong LOS component; otherwise, it is Rician.

As the portable moves, different scatterers and terrain change the plane waves incident on the portable antenna. Therefore, superimposed on the rapid multipath fading are slow variations in the average field strength of the interference pattern due to these new reflection and diffraction paths. This slower fading phenomena is called shadow fading and has a lognormal distribution.

As the portable moves away from one base station toward another, the signals received from the first base station become weaker due to increased distance from the base station or path loss, and those received from the second base station become stronger. This very slow effect is often masked by

multipath Rayleigh fading and lognormal shadow fading. Short-term Rayleigh fading is usually handled in mobile system designs by diversity techniques such as frequency hopping, multiple receivers, or correlators with variable delay lines and antenna diversity, and signal processing techniques such as bit interleaving, convolutional coding, and equalizers.

The longer-term shadow fading is usually compensated for in the system link budget margins by increasing transmitter power and co-channel reuse distance. Slow fading can usually be tracked by power control of the portable device.

The path loss component of fading must be handled by handing off to the new base station when the signal from the old base station becomes unusable. Handovers in response to multipath or shadow fading will usually result in too many handovers. In addition, since it takes from 20 ms to several seconds to implement a handover, such a strategy is not even an effective remedy for fast fading. However, the detection and measurement of fast fading can play an important role in the handover detection and decision process. This may be especially true when we consider handing off between high- and low-tier radio systems or between macro- and microcells of the same system. Such is the case when the portable is in a vehicle moving at highway speeds through microcells. In this case, even though the signal quality and strength from the low-tier base station may be momentarily better than that from the serving macrocell or high-tier base station, a handover might not be practical because the vehicle's speed will move the communicating portable too rapidly through the coverage area of the low-tier base station. This can cause the network to perform too many handovers or cause these handovers to be required so rapidly that they become ineffective due to the delay in setting them up. Thus, it can be appreciated that if the portable velocity can be detected, this would be an aid to the handover detection and decision-making process.

Handover Detection Strategies

Three handover detection strategies have been proposed for PCS networks. The schemes whereby the portable controls the handover are called *mobile-controlled handover* (MCHO) in the literature, and schemes whereby the network exercises control are called *network-controlled handover* (NCHO). There is a third class, where the network controls the handover but the portable assists with measurements of the links. This is called *mobile-assisted handover* (MAHO). The evolution of mobile communications is toward more decentralization, implying that both the management and setup of handover procedures will be partially or fully entrusted to the portable. These three strategies will be described, as will air interface standards which implement them.

Mobile-Controlled Handover – MCHO is the most popular technique for low-tier radio systems and is employed by both the European Digital European Cordless Telecommunications (DECT) and the North American Personal Access Communications System (PACS) air interface protocols. In this method the portable continuously monitors the signal strength and quality from the accessed port and several handover candidate ports. When some handover criteria is met, the portable checks the "best" candidate port for an available traffic channel and launches a handover request.

The combined control of automatic link transfer (ALT) (handover) and time slot transfer (TST) (handover between channels on the same base station) in the portable is considered desirable in order to:

- Off-load this task from the network
- Ensure robustness of the radio link by allowing reconnection of calls even when radio channels suddenly become poor

- Control both handover and handover between channels on the same base station in the same place

thus preventing unhelpful simultaneous triggering of the two processes [6, 4]. The control of handover in the portable is made possible by the portable's capability to make quality measurements of the current and candidate channels. The control of handover between channels on the same base station in the portable is made possible by passing uplink quality information (in the form of a word error indicator) back to the portable on the downlink. Quality maintenance processing, described schematically in Fig. 2, consists of four components:

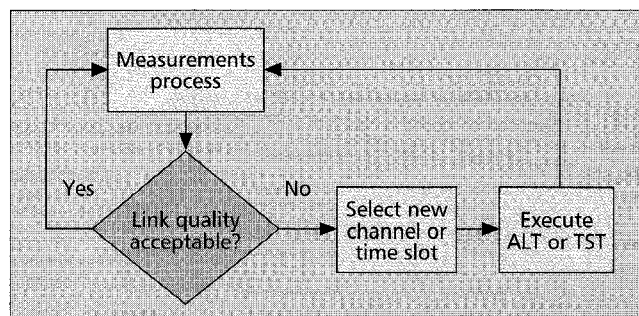
- Ongoing measurements and processing of measurement data which allows the portable to monitor quality
- The trigger decision mechanism, whereby the portable uses the processed measurement data to determine that some action (handover or handover between channels on the same base station) is required
- The choice of the new frequency carrier for handover or the new time slot for handover between channels on the same base station (a process closely allied with the trigger decision)
- Execution of the handover or handover between channels on the same base station (e.g., via a signaling protocol between the portable and network equipment)

In other words, in a portable an ongoing measurement process examines radio link quality information [4, 5]. When certain criteria are reached, the process indicates the need for a handover. It then selects a channel. Finally, the portable, in concert with the network, executes the handover. The available link quality information is obtained through various means, and is "data-reduced" in such a way to provide a manageable amount of data, while retaining enough information to make good decisions about quality maintenance actions. As part of the demodulation process, the portable receiver generally obtains two pieces of information: RSSI and QI.

Measurements of QI for the current channel are available to the portable once per frame as a result of the demodulation process. During the period of each TDMA frame where the portable is not receiving or transmitting information for the current call, the unit has adequate time to make a diversity measurement (QI and RSSI for each antenna) of at least one additional channel. The downlink WEI also is available to the portable. The base station can also feedback uplink WEI to the portable. This information would only require 1 bit of the downlink stream per burst.

Finally, handover between channels on the same base station must also be handled in the same context. This is done to ensure that handover between channels on the same base station, which mitigates only the uplink situation, will not be performed when a handover could be used to substantially improve both the uplink and downlink. In PACS, because of the use of time-division multiplexing (TDM) on the downlink, the use of the uplink word error feedback can indicate the need for a handover between channels on the same base station. Because DECT uses dynamic channel allocation, both the uplink and the downlink can be improved by a channel transfer to the same base station. The handover times for DECT have been reported to be as low as 100–500 ms. For PACS it is about 20–50 ms.

Network-Controlled Handover – NCHO is employed by the low-tier CT-2 Plus [32, 13] and the high-tier Advanced Mobile Phone Service (AMPS) [1] cellular system. In this method, the port monitors the signal strength and quality from the portable, and when these deteriorate below some threshold, the network arranges for a handover to another port. The network asks all the surrounding ports to monitor the signal from the portable and report the measurement results back to the



■ **Figure 2.** Portable quality maintenance processing.

network. The network then chooses a new port for the handover and informs both the portable (through the old port) and the new port. The handover is then effected. In current analog cellular systems (AMPS, TACS, NMT, and NAMPS) and in the low-tier CT-2 and CT-2 Plus systems, the portable plays a passive role in the handover process. The base stations supervise the quality of all current connections by making measurements of RSSI. The mobile switching center (MSC) will command surrounding base stations to make measurements of these links occasionally. Based on these measurements, the MSC makes the decision of when and where to effect the handover. Because of the large volume of signaling traffic in the network needed to collect the information and the lack of adequate radio resources at base stations to make frequent measurements of neighboring links, handover execution time is on the order of many seconds. Since measurements cannot be made very often, accuracy is reduced. To reduce the signaling load in the network, neighboring base stations do not send measurement reports continuously back to the MSC; therefore, comparisons cannot be made before the actual RSSI is below a certain threshold.

Mobile-Assisted Handover – MAHO is a variant of NCHO where the network asks the portable to measure the signals from surrounding ports and report those measurements back to the old port so that the network can determine whether a handover is required and to which port. This handover strategy is employed by the high-tier GSM cellular standard but not by any candidate low-tier PCS radio system standards.

For MAHO, the handover process is more decentralized. Both the portable and the base station supervise the quality of the link (i.e., RSSI, WEI, and sometimes quality). RSSI measurements of neighboring base stations is done by the portable. In GSM the portable transmits the measurement results to the base station twice a second. The decision as to when and where to execute the handover is still made in the network (i.e., the base station and MSC). GSM handover execution time is approximately 1 s. In both MAHO and NCHO systems, network signaling is required to inform the portable about the handover decision made in the network (i.e., on which new channel to begin communicating), transmitted on the failing link. There is some probability that the link will fail before this information can be transmitted to the portable and the call will be forced to terminate.

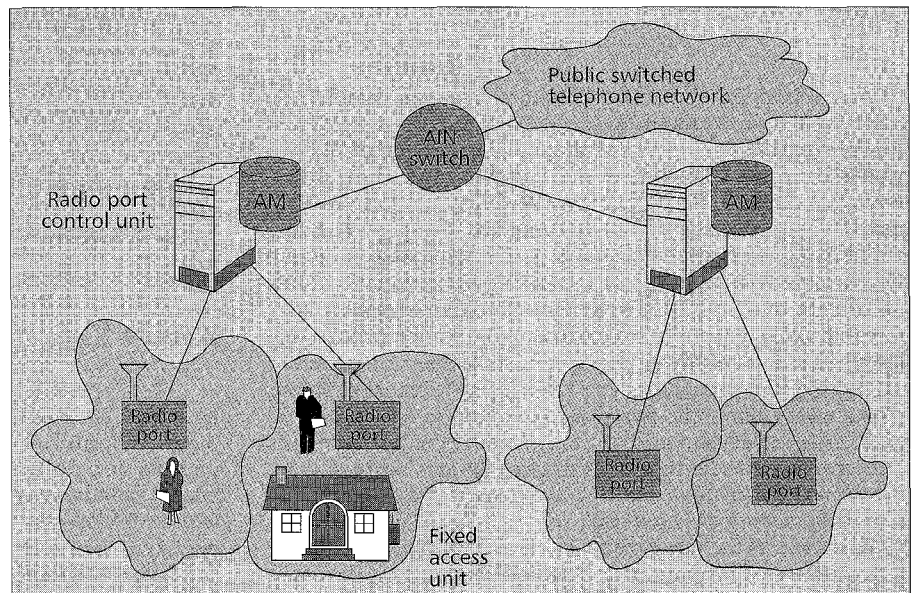
For MCHO, NCHO, and MAHO, handover failure can occur for a number of reasons. Some of them are listed below:

- There is no available channel on the selected base station.
- Handover is denied by the network, either for lack of resources (e.g., no bridge or no suitable channel card), or because the portable has exceeded some limit on the number of handovers which may be attempted in some period of time.
- The network takes too long to set up the handover after the handover has been initiated.
- The target link fails in some way during the execution of handover.

In systems using dynamic channel allocation (DCA), such as DECT, handovers can fail due to resource blocking [7].

Radio Link Transfer

We use the PACS system to illustrate the link transfer process. In the PACS architecture (Fig. 3), the portables (represented by the pedestrians in the figure) or fixed accessed units communicate with the network through the radio ports (RPs) by using an air interface (interface A), which takes the signal over the air and converts it to a wire or fiber transmittable signal. A group of channels (i.e., time slots) are assigned to each RP. Several RPs are connected to a radio port control unit (RPCU) through interface P, which separates the RP signal into logical channels. Also, the signal for managing radio function at multiple RPs is separated logically from the call traffic. The RPCU provides management and control functions between the RP and the local exchange network. Several RPCUs are connected to a switch of the local exchange network. The access manager (AM) residing in the RPCU allows the RPCU to invoke integrated services digital network (ISDN) features.



■ Figure 3. The PACS architecture.

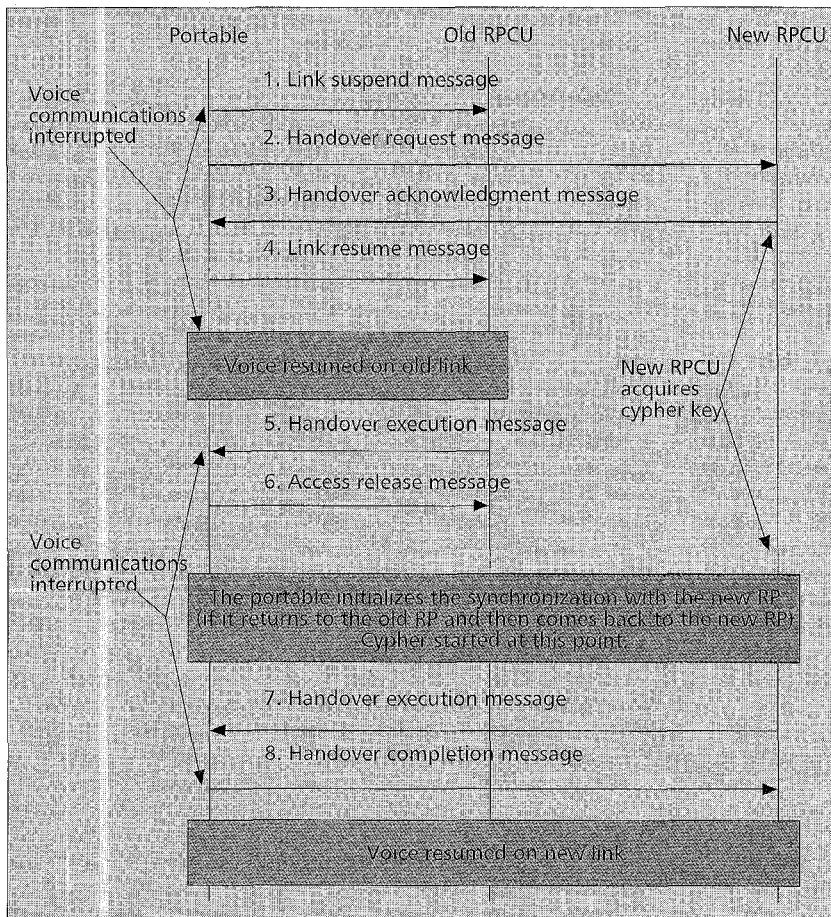
The AM functions include radio-related service control functions (e.g., multiple RP management, trunking provision, and RP-to-RP link transfers) and non-radio-related service control functions (e.g., call control, switching, and routing).

Depending on the network elements involved in handover, the PACS architecture introduces at least five distinct link transfer cases to consider. The link may be transferred between:

- Two time slots or channels in the same port
- Two ports on the same RPCU, or intra-RPCU
- Two ports connected to different RPCUs on the same switch or MSC, or inter-RPCU
- Two ports connected to different RPCUs on different switches, or interswitch
- Two ports connected to different RPCUs homing to different AMs, or inter-AM

The network implementation of handovers will vary for each of these types of handover. They will have different aspects of their control, and yet must be integrated into a unified control protocol because the portable does not know, a priori, which sort of handover will be caused by the selection of its "best" RP. In PACS, MCHO is assumed. When a handover is needed, a new radio channel is selected by the portable, and a handover request message is transmitted by the portable to the new RP. The handover can also be stimulated by the network. It is, however, still the responsibility of the portable to choose the best RP. In the case of a handover failure, the portable link quality maintenance process must decide what to do next. It may choose to initiate another handover to the "next best" channel, to simply stay on the old channel, to try again later, or to perform another action appropriate for the situation.

We use inter-RPCU handover as an example to illustrate the handover process.



■ Figure 4. Inter-RPCU handover message flow (MCHO).

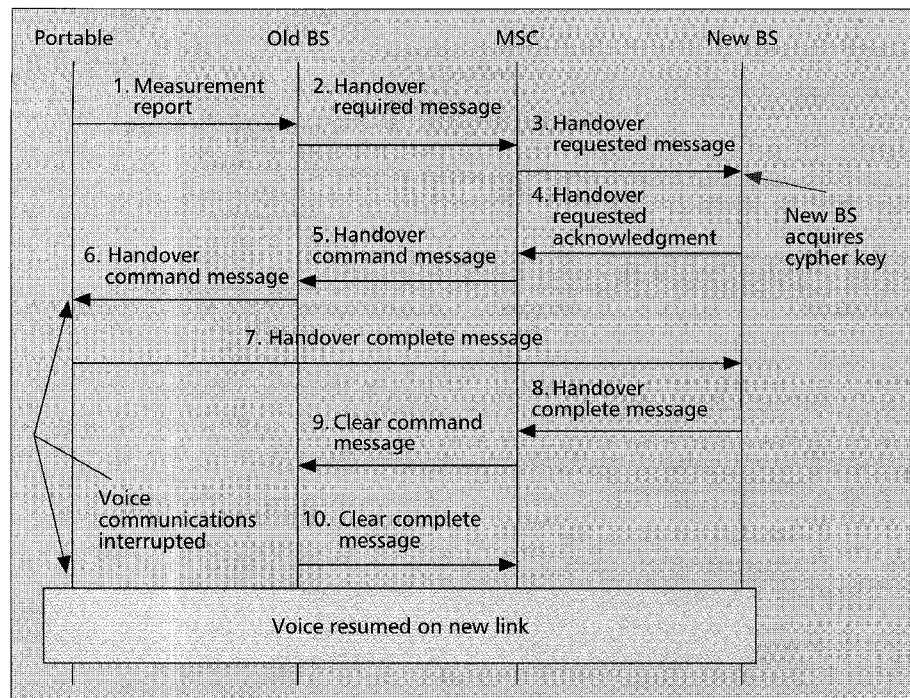
cedure in PACS. As defined above, such a handover takes place between RPs connected to different RPCUs homing on the same switch and AM. The message flow for the handover is illustrated in Fig. 4.

To initiate handover, the portable temporarily suspends the voice conversation by sending a link suspend message to the old RP (message 1, Fig. 4) and sends a handover request message through an idle time slot of the new radio channel to the network (message 2, Fig. 4). Upon receipt of the acknowledgment from the network (message 3, Fig. 4), the portable returns to the old assigned channel by sending a link resume message to the old RPCU (message 4, Fig. 4) and continues voice communication while the network prepares for the handover. Note that the handover request and handover acknowledgment are transmitted in the clear since the new RPCU does not have the cipher key for the session. Also note that handover request messages may collide with each other or with initial access attempts. That is, while one portable is seizing a channel for a handover, some other portable may seize the same channel for a handover, call origination, registration, answer, and so on. The result could be loss of both messages, or capture of one over the other.

Upon receipt of a handover request message, the RPCU checks to see if it already controls this call. If so (i.e., it is an intra-RPCU handover), it sends a handover complete message and reconfigures itself to effect the handover. If not (i.e., it is at least an inter-RPCU handover, a case studied in our example), the RPCU sends a handover acknowledgment (message 3, Fig. 4) and marks the slot busy. The network may check other parameters to ensure that it wishes to complete the handover. (For example, there may be a network management check to disallow handovers from portables which have been requesting too many of them.) If the network decides to proceed with the handover process, it transfers the session privacy key to the privacy coder associated with the new channel, and the switch inserts a bridge into the conversation path and bridges in the new port. Finally, the network informs the portable to execute the handover via both the old and new channels by sending the handover execution messages (messages 5 and 7, Fig. 4, are sent from the network to the portable via the old and the new RPs, respectively). The portable releases the old channel by sending an access release message to the old RPCU (message 6, Fig. 4). Note that messages 5 and 6 are not exchanged if the old channel fails before the new channel is established.

Once the portable has made the transfer to the new port it sends the network a handover complete message through the new channel (message 8, Fig. 4), and resumes voice communication. The network can then remove the bridge from the path and free up resources associated with the old channel. Note that by the time the network bridge is complete the new RPCU has acquired the session key from either the old RPCU or the access manager depending on the network handover protocol. Thus, both messages 7 and 8 are transmitted in the cipher mode.

The use of the bridge eliminates the necessity for exact coordination of:



■ Figure 5. Inter-BS handover message flow (MAHO).

- The switching of the path from the old RPCU to the new (by the network)
- The transferring of the conversation from the old RP to the new (by the portable)

Bridges used for handover should be inserted as quickly as possible. Bridges in common use in existing switching systems (such as "loudest talker" and "additive" bridges) are believed to be adequate. However, it is possible that specific characteristics will be required in the future, possibly necessitating specialized bridges. We note that the MCHO procedures for other PCS networks are similar to the PACS handover procedure just described. For example, DECT follows the similar MCHO procedure except that the selected new channel and the old channel may use the same carrier (frequency). The synchronization between the portable and the new base station is not necessary. Thus, the DECT handover is referred to as a *seamless* handover.

The network protocol for MAHO/NCHO and MCHO systems are different. Figure 5 shows the message flow design for handover in the GSM system using MAHO. The portable transmits the old BS the radio link measurement. In GSM, this information is updated every 0.5 s. When the old BS determines that a handover is required, it sends a handover required message (message 2, Fig. 5) to the switch. Note that in this case the handover is originated by the old BS as compared to the MCHO case, where the handover is initiated by the new RPCU.

When the switch receives message 2, it culls the list of candidate BSs supplied by the old BS, and selects the highest ranked BS with an available channel. Then it sends a handover request message (message 3, Fig. 5) to the new (i.e., selected) BS.

When the new BS acknowledges the request (message 4, Fig. 5), the switch sends the handover command message (message 5, Fig. 5) with the information regarding the new BS and the RF channel to the old BS.

The old BS commands the portable to transfer the link to the new BS (message 6, Fig. 5). The portable tunes to the new RF channel, establishes the channel to the new BS, and sends the handover completion message to the new BS (message 7, Fig. 5).

The new BS informs the switch of the handover completion (message 8, Fig. 5). The switch then clears the link to the old BS (message 9, Fig. 5). The handover procedure is completed when the old BS acknowledges the clear command (message 10, Fig. 5).

In MAHO or NCHO, the handover command (message 6, Fig. 5) to the portable is sent on the failing link. The handover procedure fails if the portable does not receive this message. In MCHO, the handover request message (message 2, Fig. 4) is sent by the portable to the new RPCU on the new, more reliable, link. Therefore, the success of the handover does not depend on any signaling message on the failing link. Another advantage of MCHO is that it is not necessary to transmit the measurement information on the air interface, thus reducing the signaling overhead required to maintain the call.

Conclusions

This article describes three major issues for PCS handover management. On the handover detection issue, we describe who initiates the handover process and how the need for handover is detected. Further reading on this issue can be found in [3-6, 10, 16-20, 23, 24, 30, 33, 34, 37].

On the channel assignment issue, we describe several strategies to handle a handover call when no channel is available in the new base station. Further reading on this issue can be found in [15, 26-28, 35, 36, 38].

On the link transfer issue, we use inter-RPCU handover as an example to illustrate the link transfer procedure in PACS. Other types of link transfer procedure are intersystem handover and interswitch handover [11, 25]. Further reading on this issue can be found in [2, 8, 9, 18, 31].

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Biographies

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