the Availability Digest

HP's Active/Active Home Location Register

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The HP Home Location Register is a NonStop active/active system that provides mobile subscriber location and profile information to the cellular network. This system is currently being used by 36 service providers on five continents serving 200 million subscribers.

We will first describe the role of the HLR in cellular networks, and will then take a closer look at HP's active/active implementation of an HLR.

What is an HLR?

Unless you are immersed in cell-phone technology, you may not know what a Home Location Register, or HLR, is. It is, in fact, the brains of a cellular telephone network. The cell towers and switches are the arms and legs of the network, but it is the HLR that is responsible for knowing *where you are* and the *services to which you are entitled*.

Knowing where you are is critical because as a mobile subscriber, you could be anywhere. Even worse, you could be on the move, changing cell towers and switches frequently during a single call connection.

The services for which HLR is responsible include those services for which you have paid, such as call waiting and encryption, as well as the current state of services over which you have control, such as call forwarding. HLR's responsibility for services is to authenticate who you are and then to authorize the services to which you are entitled.

Your current location and your authorized services are all contained in a subscriber database in some HLR assigned to you as your home HLR.[1] Any switch in the network must be able to access any subscriber database in the network in real-time to get this information.

In the early days of cell telephones, the HLR function was included in the service providers' switches. It was these switches that received call requests from cell phones and established connections to the called parties. Therefore, it was only logical that they track mobile users and provide them with their subscribed services.

However, this gave the switch manufacturers an inordinate power over the marketplace. If a service provider wanted to add or modify a particular function or service, it could only go to the switch manufacturer and pay sometimes a million dollars or more per switch for new functionality.

Consequently, there was a movement to standardize interfaces so that the HLR functions could be moved off of the switches and into a separate system under the control of the service provider.

[1] The term "home HLR" may seem redundant. However, in this article, we use the term HLR as an acronym, ignoring that the "H" also stands for "home."

In this way, service providers could offer new features to their subscribers at a fraction of the cost and in a much timelier manner.

Thus was born the independent HLR marketplace.

The HLR in Action

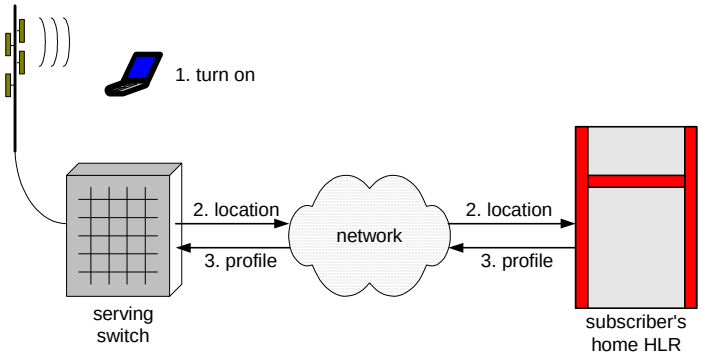
The HLR works on your behalf all the time. Any call attempt to your number will involve your home HLR.

Location

Assuming that you are in a serviced area, as soon as you turn on your cell phone it starts searching for signals being transmitted from cell towers in your vicinity. It may receive signals from several service providers. If a signal from the service provider with whom you are signed up is received, your cell phone locks onto that signal. Otherwise, it will lock onto the signal from another service provider.[2]

Via this signal, you are now connected to a local switch managed by the pertinent service provider. This switch is known as your *serving* switch.

Cellular numbers are allocated in blocks of 10,000. In effect, the first six digits of your telephone number identify your home HLR and your home switch. Your home switch is known as your *gateway* switch. Thus, knowing your telephone number, the serving switch can determine which HLR is your home HLR.



Registration

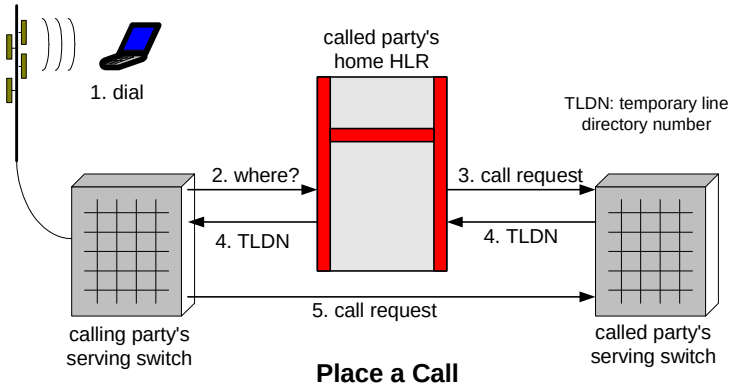
Via your gateway switch, your serving switch will inform your home HLR as to your current location. The HLR registers your serving switch in its subscriber database as your current location and returns your profile. There can be up to 500 or so parameters in your profile, depending upon the network technology. At this point, your home HLR knows where you are; and your serving switch knows the services to which you are entitled.

Placing a Call

When you want to place a call, you dial the number you are calling and push Send. This sends the number via a cell tower to your serving switch – that switch which serves the cell tower closest to you.

[2] This is known as “roaming.” Roaming connections used to be handled differently and incurred extra charges; but with the advent of HLR systems, this distinction has all but disappeared. In effect, all calls are now roaming calls.

The first task for your serving switch is to determine where the party you are calling is currently located. That information is contained in the called party's home HLR. Your call is routed to the called party's gateway switch. When the call arrives, the called party's gateway switch queries its associated HLR to find the switch with which that cell phone is currently registered (this having been determined in the same way as described earlier).

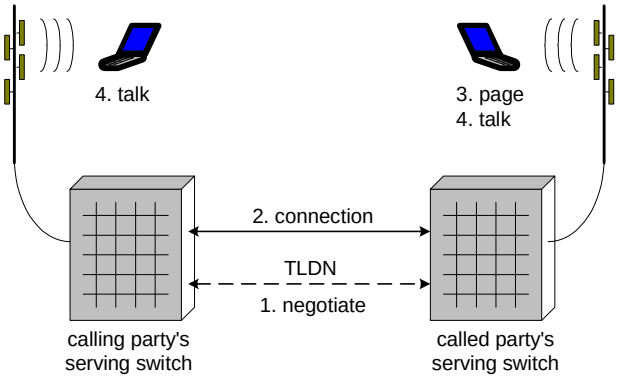


Place a Call

Rather than returning the called party's location to your serving switch, the HLR passes on the call request to the switch which is registered as the called party's serving switch. That switch returns a special telephone number through the HLR to your registered switch. This telephone number is called a temporary line directory number, or TLDN, and is a number that your switch will use to contact the called party's serving switch to negotiate a call establishment.

Establishing the Call

At this point, the called party's serving switch will work with your serving switch to establish a connection between you and your called party. Once this has been accomplished, your called party's phone is paged. If the phone is answered, you can begin your conversation.



Connect a Call

At the end of the conversation, one of you hangs up; and the switches close the connection.

If one end of the call is a regular phone and not a cell phone, the procedure is similar except that there is no record of the fixed telephone in any HLR. The regular telephone deals with a land-line switch rather than a serving cellular switch. If both ends are non-mobile phones, then the HLR is not involved.

To improve efficiency and reduce call setup time, some switches will cache profile information in their internal memory for as long as a subscriber is in their area. In that way, they can reduce significantly the amount of traffic to remote HLRs.

The Impact of Downtime

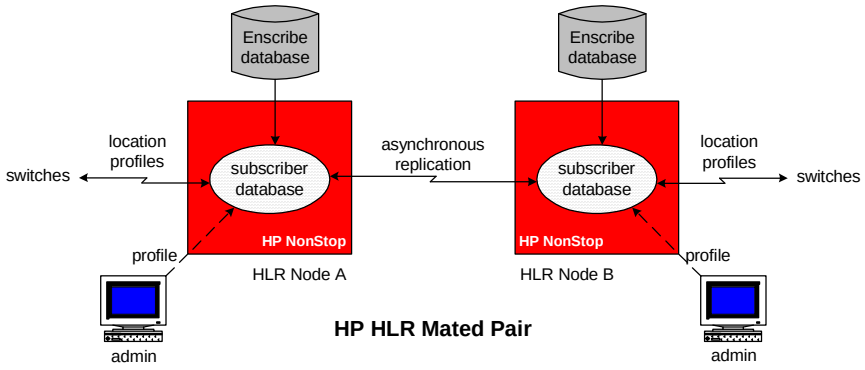
The loss of an HLR is a catastrophic event for the cellular network. Subscribers homed to that HLR are, in effect, out of service. They cannot receive calls and in most cases cannot initiate calls. However, government regulations require that service providers in the United States always provide a 911 connection for emergency calls.

Therefore, it is of utmost importance that the HLR be highly reliable. A typical HLR specification calls for five 9s availability. Still, this is five minutes of downtime per year. Six or seven 9s is a more appropriate level of availability (30 seconds or 3 seconds, respectively, of downtime per year).

The HP NonStop HLR

The Achievement of Extreme Availabilities

HP's HLR offering, part of its OpenCall suite of products for the telecommunications market, is aimed directly at those service providers who demand extremely high levels of availability. It uses a pair of NonStop servers in a mated pair active/active configuration.



HP HLR Mated Pair

Since a single NonStop server has been field-proven to provide four 9s of availability, and since an active/active system will fail over without delay to a surviving node in the event of a node failure, availabilities well in excess of five 9s are achieved. (Theoretically, this configuration is capable of providing eight 9s of availability as demonstrated in our article, Calculating Availability – Redundant Systems, published in the October issue of the Availability Digest. However, highly unlikely faults such as operator errors that can affect both nodes serve to compromise this theoretical availability to some extent.)

The HLR Active/Active Configuration

The number of HLRs in a service provider's network is a function of the size of the network, both in terms of call volume and geographical distribution. Each HLR in a mated pair is seen by the network as a separate and independent HLR. Thus, if a network has four mated pairs, it functionally has eight HLRs.

However, each HLR is backed up by its companion in its mated pair. Each HLR contains a copy of the other's subscriber database and keeps it current via asynchronous replication. Should an HLR fail, the signal transfer points (STPs) in the network (in effect, the network routers) recognize the failure and have the intelligence to route all further requests to the backup HLR. Likewise, when the failed HLR is returned to service, the STPs will once again route appropriate requests to the recovered HLR.

The HP HLRs can be deployed in an "n+1" configuration. In this case, each HLR maintains copies of the databases of n other HLRs. Should an HLR fail, the requests that it would normally handle can be distributed across the remaining HLRs. This significantly eases the additional load imposed on other HLRs during an HLR failure.

To achieve the extremely high availabilities that HP is seeking with their HLR, there can be no planned downtime. Zero! The mated pair and n+1 configurations allow zero downtime upgrades by taking down one node at a time, upgrading it, returning it to service, and then repeating this procedure for another node. During the time that a node is down for upgrade, traffic is rerouted to the other HLRs just as if that node had failed.

Memory-Resident Databases for High Performance

In order to maximize the call volume that an HLR can handle, the entire subscriber database is kept in memory. Therefore, no disk activity is required to respond to requests for location and profile information from the switches. As a consequence, the HP HLR is incredibly space efficient and supports five million subscribers per square meter of floor space.

A copy of the subscriber database is, of course, maintained on disk for initialization and persistence. In the HP HLR, this is kept in an Enscribe database to maximize performance.

Whenever a change is made to a subscriber's location or profile, this change is replicated to the other HLRs in the active/active network, whether these HLRs are configured as a mated pair or as an n+1 configuration.

Location changes are received from the switches. Profile changes can be received from administrative staff entering new services to which the subscriber has subscribed or by the subscriber himself (for instance, changing a call forwarding destination). Changes are replicated in real time and are available even if the subscriber is still in the middle of a call.

Asynchronous Replication

Subscriber database changes are replicated among the HLR systems using HLR's asynchronous Application Database Synchronization (ADS) replication engine. ADS replicates directly from the source's memory-resident database to the target's memory-resident database, thus achieving very short replication latency times. When a memory-resident database is updated by ADS, the changes are then written to the disk-resident copy of the database.

ADS is a specially developed replication engine for two reasons. First, it was needed long before third-party replication engines were readily available – the first HP HLR system was installed in the early 1990s. Second, the application required memory-to-memory replication rather than disk-to-disk replication, a capability that still is not generally supported by third party products.

The History of HP's HLR

The path to today's HP HLR has been a long one. In the early 1990s, a major third-party provider to the Tandem marketplace, ACI, was acquired by US West. A US West customer, McCaw

Cellular, saw the need for an independent HLR to free the service providers from the switch manufacturers; and US West had ACI's development staff develop the first HLR version. This was successfully installed in 1991.

There was a five-year hiatus before another HLR was sold, but then about forty systems were sold over the next three years..

US West then sold ACI with its HLR product line to Tandem Computers. Tandem allowed ACI management to buy back the company but it kept the HLR product line. Tandem was then bought by Compaq along with Digital Equipment Corporation; and subsequently, Compaq was acquired by HP. DEC also had a rich set of telecommunications products; and these products, along with the HLR product, became part of HP's OpenCall suite of telco products.

Summary

The Home Location Register is a very critical part of any cellular network. If it should fail, the network fails. By using active/active technology and fault-tolerant nodes, HP is providing HLRs with extreme availabilities to the cellular service provider community.