

Redundancy Technologies for Mobile Communication Networks

Liu Jingxiang, Ding Yanjing, Liu Feng

(ZTE Corporation, Shenzhen 518057, China)



Abstract:

With the growing popularization of mobile communication services, a growing demand for better Quality of Service (QoS) arises from the subscribers. An uninterrupted service provided with the network after a node failure is also expected from operators. To achieve these, duplex backup and even multiple backup functions have been gradually introduced into the network. Among redundancy technologies, dual home and luFlex are more successful. Dual home is a typical duplex backup system with activation of the standby server after the host server failure. luFlex is one of the multiple backup technologies with overhead transference to other node in switching pool after single switching node failure.

Network security is one of the key factors for guaranteeing good quality of mobile communication services. However, faults of communication network nodes are unavoidable. Since switching equipment plays an important role in mobile communication networks, its malfunctions may bring great loss. Besides, the recovery of such malfunctions always takes a long time. In order to improve network security, vendors have released various redundancy technologies, among which dual home and luFlex are two mature technologies. The present paper will analyze and compare the two redundancy technologies.

1 Dual-Home Technology

Dual-home technology offers a standby

node to one or more working nodes in a communication network. The working nodes, termed as active nodes, are switching equipments used for everyday network operation, while the standby node provides backup for it. The standby node will take the place of the active node to offer services once it detects faults of the active node. The networking models of dual-home system include 1+1 active standby, 1+1 mutual standby, $N+1$ active standby, and $N+1$ mutual standby.

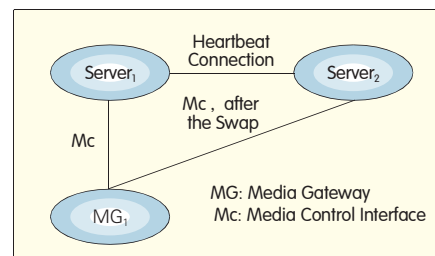
1.1 Networking Models

(1) 1+1 Active Standby

In the 1+1 active standby architecture shown in Figure 1, Server₁ is the active node, and Server₂ is the standby node. Server₁ and Server₂ have the same capacity and configuration. Mc, the media control interface^[1], is used between the servers and Media Gateway (MG). In normal working situations, MG₁ registers at Server₁, and Server₁, as the active node, offer services to the network. Once Server₁ shuts down, Server₂ is activated, and MG₁ then changes its registration to Server₂; after that, Server₂, swapping Server₁, begins to offer the services.

(2) 1+1 Mutual standby

In the 1+1 mutual standby architecture shown in Figure 2, both



▲ Figure 1. 1+1 Active standby dual-home architecture.

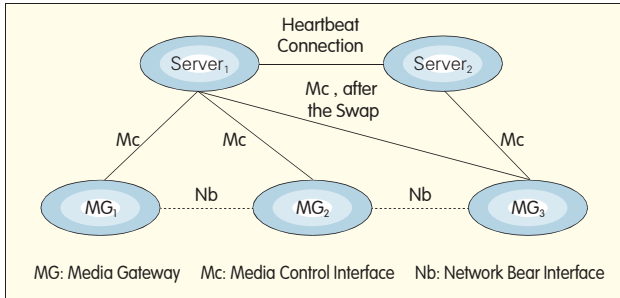


Figure 2.
1+1 mutual standby
dual-home architecture.

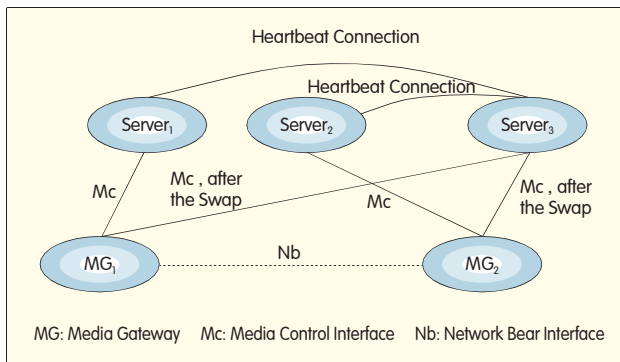


Figure 3.
 $N+1$ active standby
dual-home architecture.

Server₁ and Server₂ have their own services to process; MG₁ and MG₂ register at Server₁, while MG₃ registers at Server₂. The interface between MGs is Nb. In normal working situations, Server₁ and Server₂ just handle their own services. However, when one of them fails to work, the other will take over the services of the malfunctioned one. For example, if Server₂ has troubles, Server₁ will swap Server₂, and the registration of MG₃ will be transferred to Server₁.

(3) $N+1$ Active standby

There are N active nodes and one standby node in this architecture. The standby offers redundancy to all the active nodes. Normally, the active nodes are in operation state. If one of the active nodes shuts down, the standby node will be activated to take its services over.

The $N+1$ active standby architecture is illustrated in Figure 3, in which $N=2$, Server₁ and Server₂ are active nodes, and Server₃ is the standby. MG₁ registers at Server₁, while MG₂ at Server₂.

(4) $N+1$ Mutual standby

The difference of the $N+1$ mutual standby model from the $N+1$ active standby is that the standby node in this architecture not only backs up active nodes, but also has its own services to handle.

This model is illustrated in Figure 4, in which $N=2$, Server₁ and Server₂ are

active nodes, and Server₃ is the standby. MG₁ registers at Server₁, while MG₂ at Server₂. Server₃ needs to process its own services, and MG₃ registers at it. The services handled by Server₃ have no standby from other network elements.

1.2 Working Process

(1) Fault Detection

A heartbeat connection between a standby node and an active node is necessary for achieving the goal that the standby can detect any faults of the active. The heartbeat connection can be based on either IP or Time Division Multiplexing (TDM), however, the IP-based heartbeat is recommended for its easy networking.

The IP-based heartbeat connection may use User Datagram Protocol (UDP), Transmission Control Protocol (TCP) or Stream Control Transmission Protocol

(SCTP) to bear heartbeat signals between active and standby servers. In this case, both the servers need an IP address respectively, and IP ports for UDP/TCP/SCTP of the heartbeat connection as well.

After the heartbeat connection is built up, the active and standby nodes will keep sending heartbeat messages to each other, and wait for responses. If there is no response, it is regarded as a fault. When the number of faults reaches a threshold value, the active node is regarded as out of service.

The fault detection process also has MG registration decision mechanism to prevent false standby activation caused by temporary errors of the heartbeat connection. If heartbeat is broken, the standby node will detect if MG at the active node communicate with it for re-registration. When the number of MGs re-registered at the standby node surpasses a threshold value, the active node is regarded as out of service, and the standby node is activated to take its services over.

(2) Re-Registration of MG

MG, according to H. 248 Protocol, is able to register at more than one server in preference, and the active server has a higher priority. Once the active node works, MG sends a ServiceChange request to it for registration. Upon receiving a successful registration order, MG completes the registration process, and then the active server is configured as the MG control server^[2].

Once the active server fails to work, the signaling link between it and the MG is broken. Accordingly, the MG regards the active server as unusable, and then triggers its re-registration process at the standby server.

(3) Signaling Standby

As for the Message Transfer Part

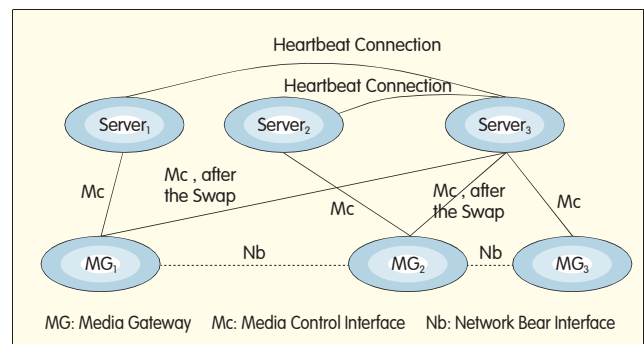


Figure 4.▶
 $N+1$ mutual standby
dual-home architecture.

(MTP) and IP, two mainstream signaling bearers in existing mobile communications networks, there are different backup solutions to them.

There are two backup schemes for MTP-based signaling protocols, including the Mobile Application Part (MAP), CAMEL Application Part (CAP), ISDN User Part (ISUP), Telephone User Part (TUP) and A interface^[3].

• Redundancy Backup of Signaling Link

There is a common Signaling Point (SP) in the active and standby configurations. Adjacent offices treat the active and standby servers as in the same office direction, and deploy MTP links to both the active and the standby. These MTP links have different Signaling Link Codes (SLCs): 0–7 for the active node; and 8–15 for the standby node.

In normal operation, the links to the active node are activated, while those to the standby node closed. Therefore, MTP Level 3 (MTP3) employs the links to the active node to transfer signaling. Once the active server has troubles, the links to the active node will be halted, while the standby server will activate its links. In this situation, MTP3 uses the links to the standby node for signaling transport.

• Route Redundancy

The active server is deployed with SP A, while the standby server with SPs A and B. Adjacent offices regard the active and standby servers as in two office directions with SP A and SP B respectively. The active server has two signaling routes: the direct active route to A, and the backup route to A via B.

In normal operation, MTP3 employs the active route to transfer signaling. If the active node fails to work, MTP3 will change to use the backup route. After receiving the MTP3 signaling with the destination point code A, the standby server will swap the active server to make a local processing.

The MTP3 User Adaptation Layer (M3UA) is used for IP bearing. There is the common SP A in the active and standby server configurations^[4]. Adjacent network elements may deploy SP A as an Application Server (AS). The AS has two sets of associations to the active and standby servers respectively. The two sets have the identical association number and bandwidth configuration.

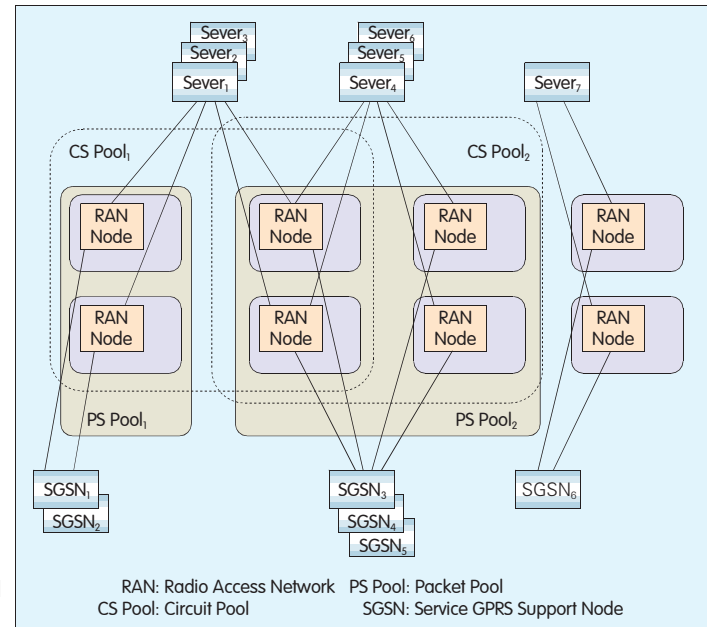


Figure 5. ▶
Typical pool
architecture.

Normally, the associations to the active server are activated, while those to the standby are inactive; the signaling to the AS is transported to the active server. Once the active server has faults, the associations to the standby are activated, and the signaling to the AS is then transferred to the standby server.

(4) Service Redundancy

The standby server should have the same service characteristics with the active server, because the former will swap the latter to provide services. To fulfill this, the synchronization between service configuration data at the active and standby servers should be supported. Any changes of service configuration data at the Operation and Maintenance (O&M) platform of the active server will be synchronized to the standby server through IP connection between the two O&M platforms.

2 IuFlex Technology

IuFlex, introduced in 3GPP R5, enables the intra-domain connection route from a Radio Access Network (RAN) node to multiple Core Network (CN) nodes. After a user initiates a service, the RAN node routes the initiation message to a suitable CN node for service processing. The RAN and CN nodes form a switch pool.

2.1 Networking Model

Figure 5^[5] shows a typical pool

architecture. As a simple illustration, the figure does not mark up the MGs in CN.

2.2 Service Process

(1) Non Access Stratum (NAS) Node Selection Function (NNSF)

The NNSF enables the RAN node to select the CN nodes by the International Mobile Subscriber Identity (IMSI) or Temporary Mobile Subscriber Identity (TMSI). It can make a user in the pool keep the access to the same CN node throughout, avoiding unnecessary location update caused by variation of user's location in pool.

The mapping relationship between IMSI and CN nodes is not fixed. The RAN node may change the mapping according to time and load.

(2) Network Resource Identifier (NRI)

An NRI exclusively identifies a CN node in the pool. One NRI cannot be reused in the pool and other intersected pools. However, a CN node is allowed to have multiple NRIs^[6].

TMSI carries the NRI message between CN and RAN nodes. The NRI message length is 0–10 bits, located at from bit 14 to bit 23 of the 32-bit TMSI^[7].

NRI has its mask, which includes NRI's bit length and its start bit in TMSI. NRI can be deduced from the TMSI and NRI mask. The NRI mask is exclusive in the switch pool.

In the pool, Null NRI is special. It is used for migration procedure of users in

the pool, and does not belong to any CN nodes.

(3) Location Update

If a user in the pool uses IMSI to initiate a location update request, the RAN node will use NNSF to define the corresponding NRI via IMSI, and routing signaling to the server that the NRI corresponds to. The server receives and handles the request. After the location is updated, the server will initiate a TMSI reallocation procedure. The reallocated TMSI includes the NRI message of the server, and is responsible for initiating the user's subsequent services. The RAN makes sure that the subsequent services are routed to the same server for processing^[9].

If a user in the pool uses TMSI to initiate a location update request, the RAN node will deduce the NRI from the TMSI and NRI mask, and, according to the NRI, get to know the server where the user has registered. The server makes location update after the request is routed to it.

(4) Calling Procedure

If a user in the pool employs IMSI to initiate a calling request, the RAN node uses NNSF to obtain NRI corresponding to the IMSI, and then routes signaling to the server corresponding to the NRI. The server handles the request, and initiates a TMSI reallocation procedure. The reallocated TMSI includes the NRI message of the server, and is responsible for initiating the user's subsequent services.

If a user in the pool uses TMSI to initiate a calling request, the RAN node will deduce the NRI from the TMSI and NRI mask, and, according to the NRI, fix the server where the user has registered. The server makes calling processing after the request is routed to it.

(5) Call Responding Procedure

The calling request includes the Global-CN-ID of the called party. If the request has IMSI, the RAN will store the relationship of the IMSI and Global-CN-ID temporarily. Once the called party uses its IMSI to respond, the RAN will use the Global-CN-ID to find the server that is responsible for handling the request respond, and send the response to it.

If the request has TMSI, the RAN will identify the connected Mobile Switching

Center (MSC) according to the NRI in the TMSI^[9].

(6) Redundancy Processing

If one server in the pool fails to work, the RAN will identify it, and transfer the service requests allocated to it to other available servers. In this way, the redundancy of servers in the pool is fulfilled.

The new server will handle location update requests initiated by the registered users at the malfunction server, and initiate a TMSI reallocation procedure. The reallocated TMSI includes the NRI message of the new server, and is responsible for the initiation of users' subsequent services.

If a registered user at the malfunction server initiates a calling, the RAN will distribute the request to an available server in the pool. However, as the TMSI in the request is not allocated by the home office of the available server, the server will refuse the calling with an excuse of unknown user. Then the user will use IMSI to initiate a location update request, and re-register at the new server through the NNSF.

(7) User Migration

User migration is another redundancy solution to luFlex network. Before a server is maintained, its users are migrated to other normally working servers, and the load remains balanced at the same time; after the maintenance is completed, the users are migrated back to the server.

Triggered by the O&M order, user migration is implemented through the following steps:

- The O&M order configures the maintained server status at the RAN node and other servers in the pool. The status is set as being uninstalled.
- The server in the uninstalled status handles services initiated by its registered users, and reallocates a TMSI with Null NRI to the user terminal. The TMSI also carries non-broadcast Local Area Identification (LAI) at the home office.
- Once the user terminal closes the current service, it will immediately use previously allocated TMSI to initiate a location update request, because the non-broadcast LAI is different from the LAI broadcast by the RAN.
- Thanks to Null NRI in the TMSI, the

RAN, after receiving the location update request, will select a new server according to the capacity of available servers in the pool, and then send the request to the selected server for location update processing and TMSI reallocation. The reallocated TMSI has NRI of the home office. During the location update, the new server deduces the user's home server from the non-broadcast LAI, and acquires the user's IMSI and authorization encryption data from its home server.

It usually takes 2–3 location update periods to complete migration of all the users of a server. Besides, user migration can be conducted on partial users of a server, so as to fulfill load adjustment among the servers in the pool.

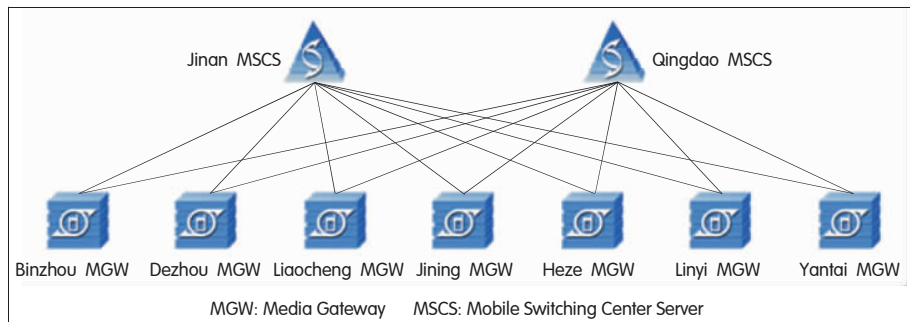
Different from ordinary redundancy, user migration is triggered by the O&M order, and requires the uninstalled server to participate in the migration process. Therefore, user migration is inapplicable to the redundancy of node down caused by a sudden disaster.

3 Comparisons of Dual Home and luFlex

The dual-home technology can fulfill redundancy of server nodes with no need of coordination of external network elements. Therefore, it is applicable to large trans-regional local networks. Operators can select proper dual-home schemes for new switching offices according to their local networking plans.

The luFlex technology involves the access network. lu interfaces of RNC are physically connected to multiple MGs in the pool simultaneously. Therefore, luFlex brings a relatively high cost for network improvement. However, as a redundancy technology, luFlex also has the capability of load sharing and management, and enables the decrease of signaling traffic in network. Accordingly, the technology is recommended for big cities with dense population and multiple switching offices.

ZTE's switching office project in Shandong is taken as an example here. In the project, new switching offices are required to be built in seven regions in Shandong, China with subscribers of from 100 thousand to 200 thousand. In order to improve O&M efficiency, every region is deployed with a MG, and two



▲ Figure 6. ZTE's dual-home networking model in Shandong.

Mobile Switching Center Servers (MSCSs) are deployed in Jinan and Qingdao separately for the MG management. Figure 6 shows the networking model of the project. As both servers have the capacity of more than 500 thousand subscribers, any server node faults may lead to large-scale network paralysis. According to the features of this networking model, 1+1 mutual standby dual-home redundancy is adopted. If one of the servers in Jinan or Qingdao fails to work, the other server may detect the faults via the heartbeat connection between them, and allows the re-registration of the MGs. Then it swaps the failed server to offer network services. Such dual-home networking not only improves the network security, but also facilitates system maintenance processes such as software/hardware upgrade, and reduces service interruptions caused by server maintenance.

4 ZTE's WCN Switch

As the kernel of ZTE's mobile communication products, its Wireless

Core Network (WCN) switch fully supports both dual-home and luFlex redundancy. It has successfully been applied in large-scale networks.

In dual-home networking, WCN, when used as a standby node, can provide 16 master nodes with redundancy backup. It supports fault detection in less than 60 s, and service recovery in less than 120 s.

In luFlex networking, WCN can support 16 switches at most in the pool to share load.

5 Conclusion

With different technological implementation, both dual home and luFlex redundancy can solve switching node faults in mobile communication networks, improving network reliability and Quality of Service (QoS). Therefore, they are getting increasing attention from the operators worldwide.

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Biographies

Liu Jingxiang



Liu Jingxiang received his master degree from Beijing Institute of Technology. As an engineer at ZTE Corporation, he is engaged in R&D of ZTE's circuit-domain products for mobile core networks.

Ding Yanjing



Ding Yanjing received her master degree from Southeast University. As an engineer at ZTE Corporation, she was responsible for R&D of ZXWN-CS, ZTE's mobile core network product, and is now engaged in R&D of ZTE's packet-domain products for mobile core networks.

Liu Feng



Liu Feng received his master degree from University of Science and Technology of China. As an engineer of ZTE Corporation, he is engaged in R&D of ZTE's circuit-domain network management system for mobile core networks. He has published a patent on regular monitoring of memory database in mobile communication equipment.

Roundup

ZTE's AWS Handset Now Available in U.S.

ZTE USA, Inc., a subsidiary of ZTE Corporation announced the general availability of the ZTE C79 handset in the U.S. market on August 21, 2008. The ZTE C79, a full-featured CDMA AWS flip phone, is being offered by carrier MetroPCS to subscribers in the U.S. market it serves.

The ZTE C79 includes over 60 MB of user memory for downloading games and applications as well as an MP3 player which includes external music keys. This unique feature will allow users to enjoy listening to music and manage

their playlists with ease. Featuring a sleek design and affordable price point, the ZTE C79 also includes a 1.3 megapixel camera, Bluetooth and picture messaging. The handset operates on AWS frequency bands in addition to the PCS and Cellular bands.

As with all its products, ZTE both designs and manufactures its handsets in-house. This end-to-end approach enables ZTE to offer feature-rich, high quality phones at an attractive price point.