VoLTE problem location method based on big data

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Abstract. This paper mainly introduces the key information extracting method from User Equipment (UE) test data, the synchronous algorithm of various interfaces X Detailed Record (XDR) data, the key information filling technique of multi interfaces X Detailed Record (XDR), the analytical procedure based on big data is descript in details. An example is given to explain that more accurate reason for Voice over Long-Term Evolution (VoLTE) call not connected can be found with big data from core network, compared with UE data only. With this method VoLTE problem can be quickly solved, it is very useful for wireless operator to improve the user voice service awareness rapidly.

1. Introduction
The structure of VoLTE is very complex with many network nodes, the LTE wireless access network bears the VoLTE user media service, IP Multimedia Subsystem (IMS) network is responsible for service control. Network construction involves the equipment upgrading of circuit domain, packet domain and IMS domain, etc [1,2]. The process of establishing, controlling and terminating VoLTE calls is complex. It is difficult to find and solve the problems of call dropped or not connected (abnormal call) by analyzing UE signal data only. With the improvement of the big data processing capacity of core network, we have a way to obtain the standardized key information of multi interfaces big data, and have an opportunity to connect UE and multi interfaces big data together for whole process of call analysis. This paper mainly describes the connection method of UE signals, multi interfaces signals of Evolved Packet Core (EPC) network and IMS network, and lists a case of call not connected problem finding process with combinations data from multi resources.

2. Combination Method of Multi Interfaces XDR Data

2.1. "UE XDR” Extract Methods from UE Singals
“China Mobile unified Deep Packet Inspection(DPI) equipment technical specification” has specified the requirements of extracting key information and formatting XDR data of S1-MME, S6a, S11, Gv, Gx, Rx interfaces involved in VoLTE call [3]. In order to connect UE data and core network data together, the key information of the total signals recorded by UE should be extracted and formatted into “UE XDR”. The format of “UE XDR” is based on the definition in the unified DPI specification, added unique information related to UE. The data that can be recorded from UE includes the processes involved in Uu, S1-MME, Mw and other interfaces in the unified DPI specification, so the characteristics of “UE XDR” data are multi interfaces and multi protocols. In order to record more detail key information used to analyze the cause of call dropped or not connected, different protocols and signalling processes of VoLTE calls are defined, so three “UE XDR” should be generated, they are “UE_CALL_XDR”, “UE_LTE_UU_NAS_XDR”, “UE_LTE_UU_RRC_XDR” [1]. And the GPS
data of UE could be extracted in order to generate “UE_LOCATION_XDR”. Other XDR could be connected with “UE_LOCATION_XDR” and then filled with GPS data. “UE_CALL_XDR” mainly records the results of the call, including normal call, call dropped and call not connected. The net type at the call end, service cell ID, cause of abnormal release in “UE_CALL_XDR” provide more accurate information for the analysis of abnormal call problems. There are many fields in “UE_CALL”, as “PROCEDURE_STATES” field is specially designed for UE data expansion. The state of “end of test log” in the “PROCEDURE_STATES” field is triggered by the end tag of UE test log, it is specially marked as the characteristics of UE data, after this state appears, the connection between “UE XDR” and “CORE XDR” will finish. UE signals are more accurate than core network signals in computing results of call abnormal end, so call end state is determined by UE signals. “DT_LOG_NAME” field in “UE_CALL_XDR” is recorded with UE test log name, because the “CORE XDR” of multiple interface of each call belongs to a pair of UE test log. One of the core methods of this study is to discover user perception problems based on UE data, then analysis and find the reason with the combined data of UE and core network. The calling number field in “UE_CALL_XDR” is extracted from the “F:< sip:+8613920500768@gd.ims.mnc000.mcc460.3gppnetwork.org >; tag = 3065822386” element in “SIP INVITE REQUEST” signal [3]. Similarly, the called number field is extracted from the downlink “SIP INVITE REQUEST” signal. As the calling and called number only appear in SIP signals, this number in other “UE XDR” comes from “UE_CALL_XDR”.

2.2. Data Synchronization of Multi Interfaces

Data synchronization method between UE and multi interfaces big data of core network is divided into two steps. The first one is based on each call of UE, in order to find the reason of an abnormal call. The second one is based on the start or end signals of multi interfaces “CORE XDR”, in order to connect the “CORE XDR” data to a whole call process [1].

The call data collection is calculated by five parameters: calling number, called number, call start time, the 3.5 seconds of adjust time at the call start, and the 3 seconds of adjust time at the call end (Figure 1). The calling number and called number are the same in each call, the interval of each call is fixed as 15 seconds. The time difference between UE and core network is very small, because they are all synchronized with NTP clock. Then all the XDR data could be collected by the same call number in "UE_CALL_XDR" and "CORE XDR". The "CORE XDR" data with 3.5 seconds time range before or after the call start time and with 3 seconds time range after the call end time in" UE_CALL XDR " belongs to the same call, then whole UE and interfaces core network data of one call is found.

![Figure 1. Method of whole call data collection.](image)

Synchronous signals should be the downlink SIP and NAS signals, as the feature that they can be transparently transmitted from core network to UE. The time of other "CORE XDR" data adjusted by the synchronous signals time, as shown in Table 1. There are three steps for data synchronization. First, make the time of core network synchronous signals equals the time of UE synchronous signals and minus 1ms, as the synchronous signals are downlink, and time of core network synchronous signals should be earlier than the time of UE synchronous signals. Second, calculate the difference time of
core network synchronous signals before and after adjusted. At last, the time of core network signals before the next core network synchronous signal should minus the difference time adjusted.

Table 1. Time adjustment of signalling synchronization.

| Time Adjustment         | Original Time(s) | Adjusted Time(s) | Computing Method                                      |
|-------------------------|------------------|------------------|-------------------------------------------------------|
| Trying                  | 4.299            | 5.861            | Synchronous signal, adjusted time is -1.562 sec       |
| Modify Bearer Res       | 4.324            | 5.886            | Inherit the adjusted time of the previous signal (-1.562) |
| Create Bearer Req       | 4.556            | 6.118            | Inherit the adjusted time of the previous signal (-1.562) |
| E-RAB Setup Request     | 4.559            | 6.027            | Synchronous signal, adjusted time is -1.468 sec       |
| E-RAB Setup Response    | 4.562            | 6.03             | Inherit the adjusted time of the previous signal (-1.468). Then this core signal has the same time of UE signal, so the time of it should added 1ms more, because it later than UE signal. |

In order to fill the key information into multi interfaces XDR, synchronous XDR information should be transmitted. Different XDR processes field backfill in the same protocol is one method, the other one is XDR processes field backfill between different protocols.

As the definition of "China Mobile unified DPI equipment technical specification", XDR generated by NAS single protocol contains MME_GROUP_ID, MME_CODE, TMSI and other information, but not all NAS layer processes contain the above fields. The fields that are not contained in these processes can be backfilled from the fields contained in other XDR processes according to the sequence. At last, the fields in different XDR processes could be backfilled in the same protocol.

Cell field is also defined in XDR generated by NAS layer protocol, but service cell information is not contained in any NAS signals. It is contained in signals of RRC layer protocol, such as System Information 1. Cell field contained in NAS XDR could be backfilled from the RRC XDR, according to the sequence of NAS and RRC process. At last, the fields in NSA XDR processes could be backfilled.

3. Method of Problem Classification

The events of call dropped and not connecting are determined by the UE signalling state machine, they are recorded in the PROCEDURE_STATUS field of "UE_CALL_XDR". The reasons of abnormal events are determined by associated multi interface XDR from big data of each call. There four main steps in calculating procedures. First, determine the call result in "UE_CALL_XDR" is normal or not; Second, determine whether there is "CORE XDR" data in this call; Third, find out whether there is an abnormal end in XDR of all interfaces involved in the call process; At last, the cause of the abnormal call is determined by the main class or subclass cause of XDR process closest to the call start time [1,4,5]. The calculation process is shown in Figure 2 [1].
The calculation methods of cause categories include the following steps:

There are four main class causes extracted from "cause_type" field in "S1-MME_XDR", "UE_LTE_UU_NAS_XDR", they are classified as "wireless network abnormal", "transmission abnormal", "NAS abnormal", "protocol abnormal" as 3GPP defined [2]. When there is an abnormal cause in "S10_XDR", "S11_XDR", "S10_XDR", "S6a_XDR", "Gx_XDR" "Sv_XDR", the main class cause is "core network abnormal".

When there is an abnormal cause in "UE_LTE_UU_RRC_XDR", "UE_MR_XDR", the main class cause is "wireless network abnormal".

When the above conditions are not met, the main class cause is "unknown abnormal".

The subclass cause is mainly determined by the specific value of "cause_type" field in abnormal process of each interface XDR, exclude the "UE_MR_XDR". The subclass cause of "UE_MR_XDR" is "weak coverage", "overlap coverage", "over-covered coverage" and etc [6].

Analysis of abnormal cases:

As an abnormal case of dropped call happened at UE in the real life. The processes of VoLTE call start, RRC connection, radio resources configuration of SRB1, SRB2 and DRB, track area update are all success, but UE receives SIP INVITE message of which SIP status code is 503 Service Unavailable from network [7]. It is impossible to find out the real reasons with the UE signal alone (Figure 3) [1].
Figure 3. The key process of UE.

But when the problem is analysed with core network signals of S1-MME and S11 interface, we can find before IMS core network send SIP 503 (warning: Media Bearer Lost) message to UE, there is an abnormal event in S1-MME interface of the E-RAB establish process, as shown in Figure 4. According to the standard process, when the IMS core network receives the INVITE REQUEST message, it will reply TRYING message to the terminal, and inquire about the strategy of PCRF; PCRF requests SGW to create dedicated bearer, SGW will send the create bear request message to MME through S11 interface. Dedicated bearer is created by UE and radio bearer channel is allocate by eNodeB with Activate Dedicated EPS Bearer Context Request message which is carried in E-RAB SETUP REQUEST transferred by S1-MME interface from MME. But at the same time, UE reports the A3 measurement event. Therefore, eNodeB needs to deal with the allocation of radio bearer channel and basestation handover at the same time. In this case, eNodeB manufacturer handle basestation handover event first, instead of allocating radio bearer channel and sending Activate Dedicated EPS Bear Context Request message to UE. In order to indicate that the bearer is not established and response the E-RAB SETUP REQUEST message, eNodeB sends E-RAB SETUP RESPONSE message which carries the failure cause (Radio NetWork: X2 Handover triggered) to MME. The dropped call is directly caused by SIP 503 (warning: Media Bearer Lost) which is send from IMS, but the deep reason is the failure of bearer establishment. The deep network problem can be found by using the end-to-end automatic problem location method, as shown in Figure 5 [1].
Figure 4. Signalling association between UE and core network.

Figure 5. Reason of the call not connected.

4. Conclusion
The application of big data analysis technology in network optimization is a very important research direction. Massive core network data provides us with macro network quality indicators. At the same time, it is also a key technology to deeply analyze the abnormal problems in big data, and then locate and solve the problems. With the continuous improvement of unified DPI technology, the integrity and accuracy promotion of XDR data in core network, the automatic problem location method for VoLTE will be more widely used. This method is very advanced at the VoLTE problem solved with big data.

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