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OPTIMIZING AAA-DRA-OCS CONNECTIVITY IN DIAMETER ARCHITECTURES: THE CASE OF « DIAMETER_REALM_NOT_SERVED (3003) » ERRORS AND «DIAMETER_UNABLE_TO_DELIVER (3002) » ON THE Ro INTERFACE

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Abstract
This article addresses the optimization of connectivity between AAA server, DRA router, and OCS (Online Chariging System\0, real time billing platform components in Diameter-based architectures, focusing on critical errors such as DIAMETER_REALM_NOT_SERVED (3003) and DIAMETER_UNABLE_TO_DELIVER (3002) on the Ro interface.

Through a field analysis of network traces and system configurations in a real LTE environment, recurring errors were identified, particularly those related to misconfiguration of routing parameters during the initial integration phase.

Practical solutions and technical recommendations are proposed to enhance Diameter routing reliability and ensure efficient real-time charging.

Keywords : *Diameter, AAA, DRA, OCS, Ro Interface, Realm, Routing, Error 3003, Error 3002, Optimization, Telecommunications*

1. Introduction

The sustained growth of fourth-generation (LTE) mobile networks and the expansion of real-time online services have placed the Diameter protocol at the heart of signaling exchanges for authentication, authorization, and billing (AAA) functions, involving in particular the authentication server, the Diameter Routing Agent (DRA), and the online billing system (OCS). In this context, the Ro interface plays a key role in the exchange of Gy messages, which govern real-time billing events.

The increase in Diameter traffic leads to complex signaling architectures that are prone to malfunctions, particularly in the event of routing errors or message delivery errors (Nokia, 2023; Telecompedia , 2025).

Two critical error codes frequently emerge on Ro:

- **Diameter_Realm_Not_Served (3003)** indicates that the destination domain is not recognized or supported by the DRA or target network.
- **Diameter_unable_to_deliver (3002)** indicates that the message cannot be routed to the desired result, often due to *Destination -Host* and *Destination -Realm matching problems* , or an inadequate network path (Oracle, 2024; Nokia, 2023).

The occurrence of these errors on Ro directly impacts the reliability of online transactions, causing rejections, increased processing times, and a risk of revenue loss. Although standards specify management mechanisms, such as blacklist failover or ignoring Destination -Hosts for retransmission, these methods can induce instability and increased latency (Nokia, 2023).

It is therefore essential to optimize AAA DRAOCS connectivity -in order to guarantee the robustness and resilience of exchanges, minimize protocol errors, and improve service continuity.

2. Observation

In modern mobile networks, the AAA (Authentication, Authorization, Accounting) architecture relies on the Diameter protocol to ensure communication between elements such as AAA agents, DRAs (Diameter Routing Agents), and OCS (Online Charging) servers. Systems). However, errors such as DIAMETER_REALM_NOT_SERVED (3003) or DIAMETER_UNABLE_TO_DELIVER (3002) persist during a new integration, delaying project progress and affecting real-time billing via the Ro interface.

3. Problem Statement

In Diameter architectures, connectivity between AAA (Authentication, Authorization, Accounting) components, the Diameter Routing Agent (DRA), and the Online The Charging System (OCS) is essential to ensure real-time billing and service continuity. However, during a new AAA server integration, frequent errors such as DIAMETER_REALM_NOT_SERVED (3003) and DIAMETER_UNABLE_TO_DELIVER (3002) on the Ro interface impact project delivery times.

These anomalies reveal deficiencies in the configuration of Diameter routes, the management of Destination-Realm and Destination-Host attributes, as well as in the alignment of certain configuration parameters (Transport Protocol, Attribute - Value-Pair(AVP) incompatibility), thus causing a significant delay in going into operation.

We formulate the main question of our research as follows:

How to optimize AAA DRAOCS connectivity -to reduce DIAMETER_REALM_NOT_SERVED (3003) and DIAMETER_UNABLE_TO_DELIVER (3002) errors on the Ro interface when integrating a new AAA server?

3.1. Specific questions

- What are the technical causes of errors 3002 and 3003 when integrating an AAA server into a Diameter architecture?
- What routing and configuration strategies can guarantee time savings and reduce these anomalies?

4. Main Hypothesis

- H1: Communication or exchange of configuration data in the form of an Excel file allows for a significant reduction in errors 3002 and 3003.
- H2: Errors 3002 and 3003 are mainly related to inconsistencies in the configuration of Diameter routes and attributes (*Destination-Realm* , *Destination-Host*) during AAA server integration.
- H3: Optimization of routing tables and alignment of the parameters " Attitude -Value-Pair (AVP) = Subscription -Id-Type" between OCS and AAA.

5. Objective

Identify the causes of these critical errors during integration and propose concrete technical solutions and recommend good AAA-DRA-OCS integration practices.

6. Definition of concepts related to the study

6.1. AAA (Authentication, Authorization, Accounting)

AAA encompasses three essential functions in IP and telecom networks:

- **Authentication** : Verification of the user's identity before accessing the network.
- **Authorization:** Allocation of rights and available services.
- **Accounting:** Tracking and recording the use of resources for billing or auditing.

These functions are usually centralized in an AAA server, using protocols like Diameter (Tschofenig et al., 2019).

6.2. Diameter Protocol

Diameter is a signaling protocol standardized by the IETF (RFC 6733) to replace RADIUS. It provides session management, real-time billing, and secure data exchange in LTE/IMS networks. Diameter relies on Attribute -Value Pairs (AVPs) and specific interfaces, including Ro for online billing (Cellusys , 2023; FreeDiameter , 2021).

6.3. DRA (Diameter Routing Agent)

The DRA is an intelligent node responsible for routing Diameter messages between AAA, OCS, and PCRF components. It applies policies based on Destination-Realm and Destination-Host attributes, ensuring the correct distribution of requests in multi-carrier environments (Telcovas , 2023; Nokia, 2023).

6.4. OCS (Online Charging System)

OCS is the real-time billing system for mobile operators. It receives requests via the Ro interface (Gy messages) and applies tariff rules instantly, which is crucial for prepaid services and digital content (Lee, 2025; Oracle, 2024).

6.5. Ro Interface

Ro is a Diameter interface defined by 3GPP (TS 32.299) for online billing. It carries Gy messages between the AAA server and the OCS, enabling credit validation before service consumption (3GPP, 2025).

7. DIAMETER_REALM_NOT_SERVED (3003) and DIAMETER_UNABLE_TO_DELIVER (3002) errors

- **3003 (Realm Not Served)** : indicates that the domain (*Destination-Realm*) is not recognized or supported by the DRA or target network.
- **3002 (Unable to Deliver):** indicates the inability to route the Diameter message to the destination, often due to incorrect routing or incomplete configuration (Oracle, 2024; Telecompedia , 2025).

8. Optimization of AAA-DRA-OCS connectivity

It consists of improving the reliability and performance of Diameter exchanges by:

- the optimal configuration of routes and attributes,
- the implementation of adaptive switching mechanisms,
- and proactive monitoring to avoid service interruptions (Cellusys , 2023; Nokia, 2023).

9. Methodology

This study adopts an applied experimental approach aimed at analyzing and reducing DIAMETER_REALM_NOT_SERVED (3003) and DIAMETER_UNABLE_TO_DELIVER (3002) errors on the Ro interface during the integration of a new AAA server.

10. Search Type

A technical and practical research -, oriented towards the resolution of an operational problem in Diameter architectures (Tschofenig et al., 2019).

11. Study framework

The target environment includes AAA, DRA, and OCS components, interconnected via the Ro interface for real-time billing (3GPP, 2025). The DRA is the central routing point for Diameter messages, applying Destination-Realm and Destination-Host based policies (Telcovas , 2023).

12. Population and sampling

The tests are based on online billing sessions (CCR/CCA) simulated in pre- -production via freeDiameter and validated in production on canary traffic (Oracle, 2024).

13. Data Collection

The data comes from DRA/AAA/OCS logs (Result -Code, CCR→CCA latency, DWR/DWA), Wireshark captures for protocol analysis, and OCS counters for performance indicators (Cellusys , 2023).

13.1. Variables and indicators

- **Independent variables:** Diameter route configuration, attribute normalization (Destination-Realm, Destination-Host), AVP adjustment and TCP instead of SCTP.
- **Dependent variables:** Error rate 3002/3003, CCR→CCA success rate, average latency, number of retries (Telecompedia , 2025).

14. Middle

Huawei equipment , with a centralized architecture including AAA, DRA and OCS nodes.

Figure 1 illustrates the bidirectional message flow between key components of the Diameter architecture on the Ro interface: the enterprise client initiates a request to the AAA server, which forwards it to the Diameter Routing Agent (DRA), and then to the Online Charging System (OCS). Each component also exchanges responses, thus ensuring complete real-time processing of billing transactions.

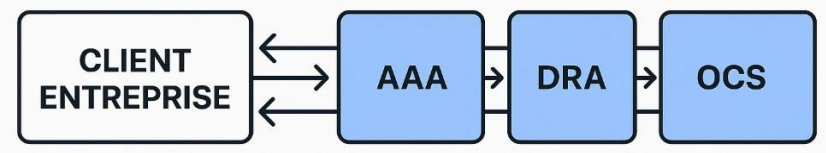

Figure 1: The flow between the different nodes in Diameter/Interface Ro

15. Data Collection

Data collection took place in an operational LTE environment, with particular attention paid to the Ro interface between the AAA , the DRA and the OCS.
Four main sources of data were used:

- **Wireshark captures on the Ro interface:** Network traces were recorded at the time of the exchange of CCR (Credit Control Request) /CCA (Credit Control Answer) messages between AAA and OCS via the DRA, in order to identify specific errors such as DIAMETER_REALM_NOT_SERVED (3003) and DIAMETER_UNABLE_TO_DELIVER (3002).
- System logs (AAA, DRA, OCS): Log files from Huawei equipment and the AAA server were analyzed to detect routing failures, SCTP transport errors instead of TCP as exchanged in the Excel configuration file, timeouts, and session rejections.
- Analysis of failed CCR/CCA messages : Each erroneous message was examined in detail, focusing on key attributes such as Destination-Realm, Destination-Host, Route-Record and Result -Code, in order to understand the nature of the failure.
- Diameter configuration review: The signaling element configuration files were inspected to verify the consistency of Realms (domains), the TCP and not SCTP transport protocol, routing tables, and relay policies, which are often responsible for the errors studied.

This multi-source data collection made it possible to cross-reference observations and strengthen the reliability of the results.

16. Participants

The participants in this study are technical experts involved in network architecture and configuration (Datacom), configuration, management, and operation of AAA, DRA, and OCS components in real-world LTE environments. These include:

- Core network engineers responsible for configuring Diameter protocols, routing and session monitoring.
- AAA and OCS system administrators, responsible for provisioning, billing rules and log monitoring.
- Experts in mobile architecture, involved in validating integration and resolving incidents related to Diameter signaling, IP path and network firewall.
- Supervisory operators who provided feedback on the operational impacts of observed errors.

Interaction with these professionals took place via technical meetings, configuration reviews, cross-analysis of logs, and validations in a real production environment.

17. Results

Analysis of the collected data revealed the following points:

17.1. Recurring errors identified

- Device-Watchdog proactive connectivity tests Request (DWR)/ Device-Watchdog Answer (DWA) while the Pings and tracert were good;
- No messages Capabilities -Exchange Request (CER)/ Capabilities -Exchange Answer (CEA);
- DIAMETER_REALM_NOT_SERVED (3003);
- This error is caused in particular by an incorrect declaration by AAA of the route to the OCS/CCS domain via DRA.
- In this specific case, AAA was sending the request to the wrong destination domain (Realm), which generated the error.
- The fix, at the AAA level , consisted of sending the CCR request to the destination domain belonging to CCS/OCS via DRA.
- You will notice that IP addresses and ports as well as domain names are hashed to comply with non-disclosure clauses.

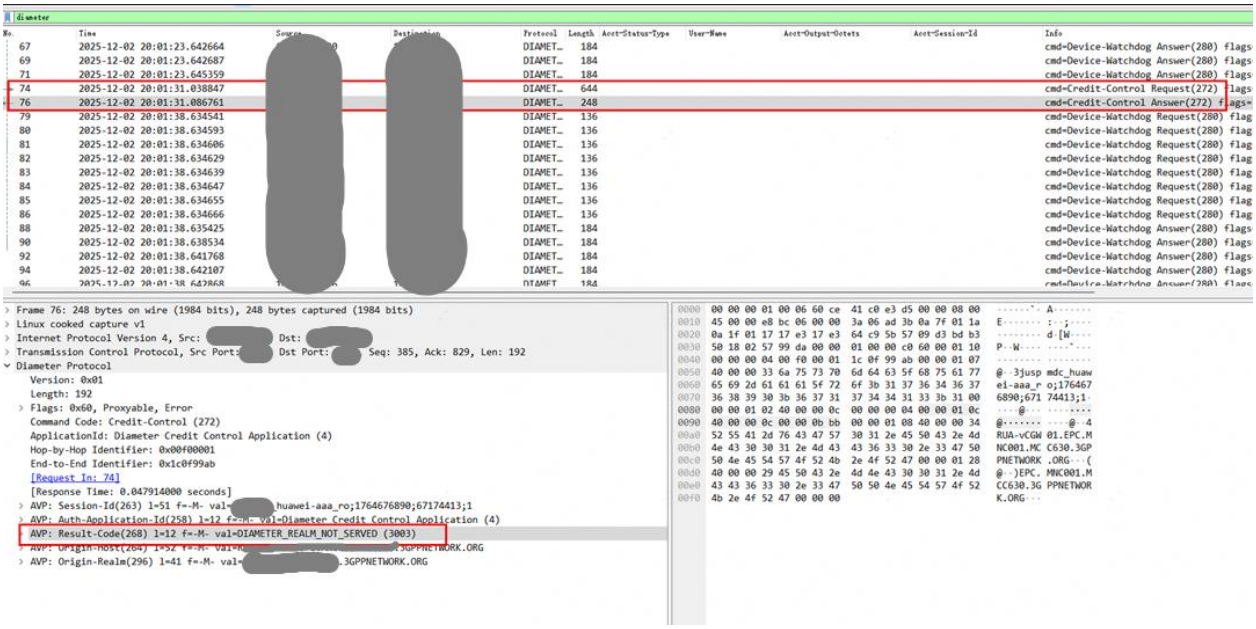

Figure 2: Wireshark screenshot of error 3003
Source: Captured by myself during real-world testing

- DIAMETER_UNABLE_TO_DELIVER (3002);
- After correcting the error in routing to the correct destination domain, another error appeared. This is the "DIAMETER_UNABLE_TO_DELIVER (3002)" error, represented by Figure 3.

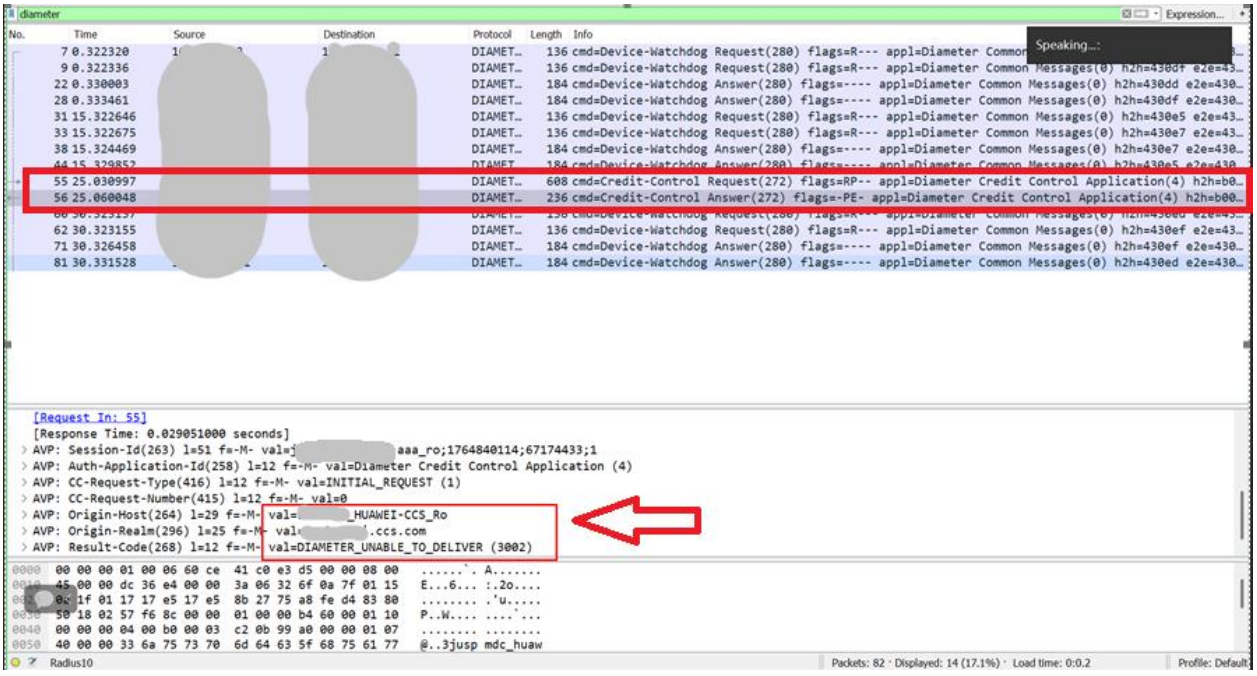

Figure 3: Wireshark screenshot of error 3002
Source: Captured by myself during real-world testing

After investigation, we discovered that this response originated from CCS/OCS. It is related to the incompatibility of the Attribute -Value-Pair(AVP) = Subscription -Id-Type: END_USER_NAI (3) between the AAA server and OCS/CCS.

As we can see in the screenshot below , the AAA server was using type 3 while OCS/CCS was using type 2.

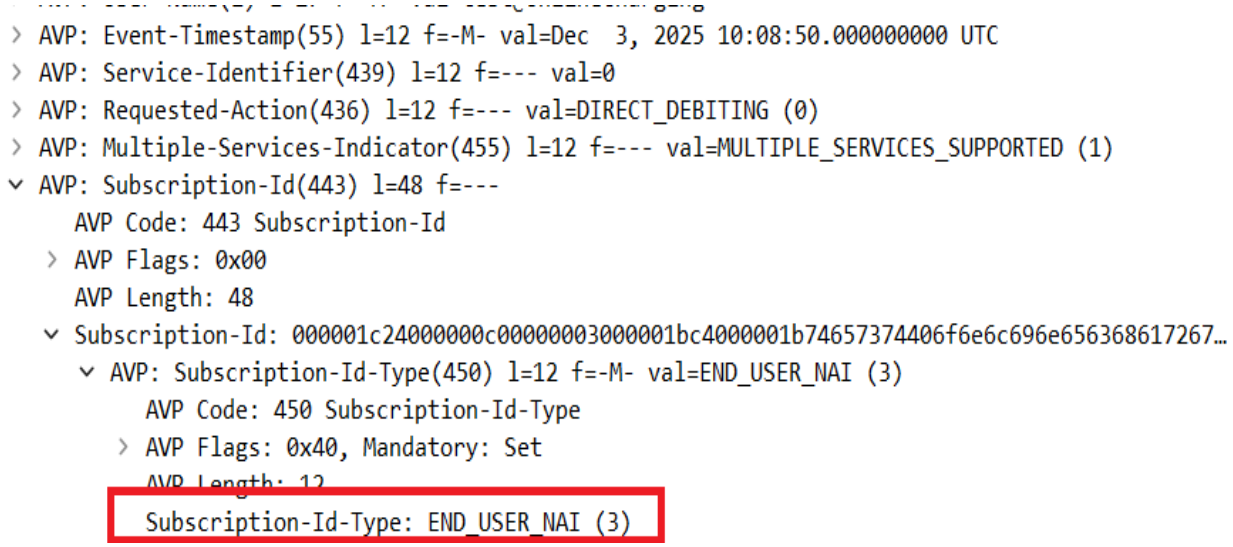

Figure 4: The Subscription-Id-Type value (3) of AAA

Source: Captured by myself during real-world testing

Note that in the Diameter protocol, AVP stands for " Attribute -Value Pair." AVPs are the basic elements used to carry information in Diameter messages. Each AVP contains:

- a code (indicating the type of information, e.g., User-Name, Session-Id),
- a length, possibly some indicators (flags) , and a value.

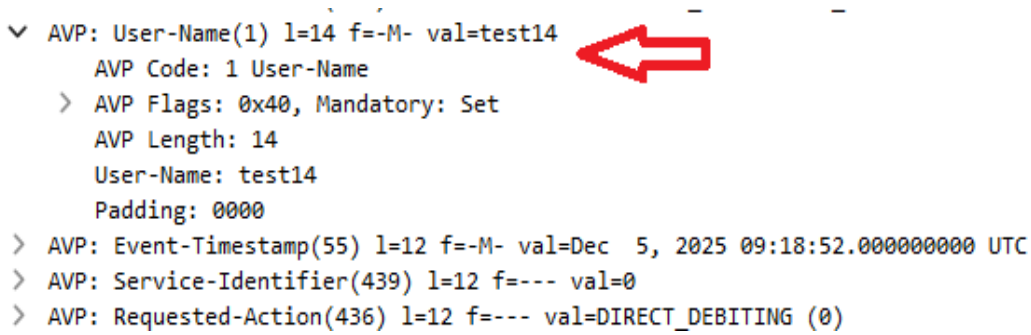

Figure 5: Illustration of some AVPs

Source: Captured by myself during real-world testing

After agreement, correction and alignment, the problem was resolved to the complete satisfaction of all parties involved in the project.

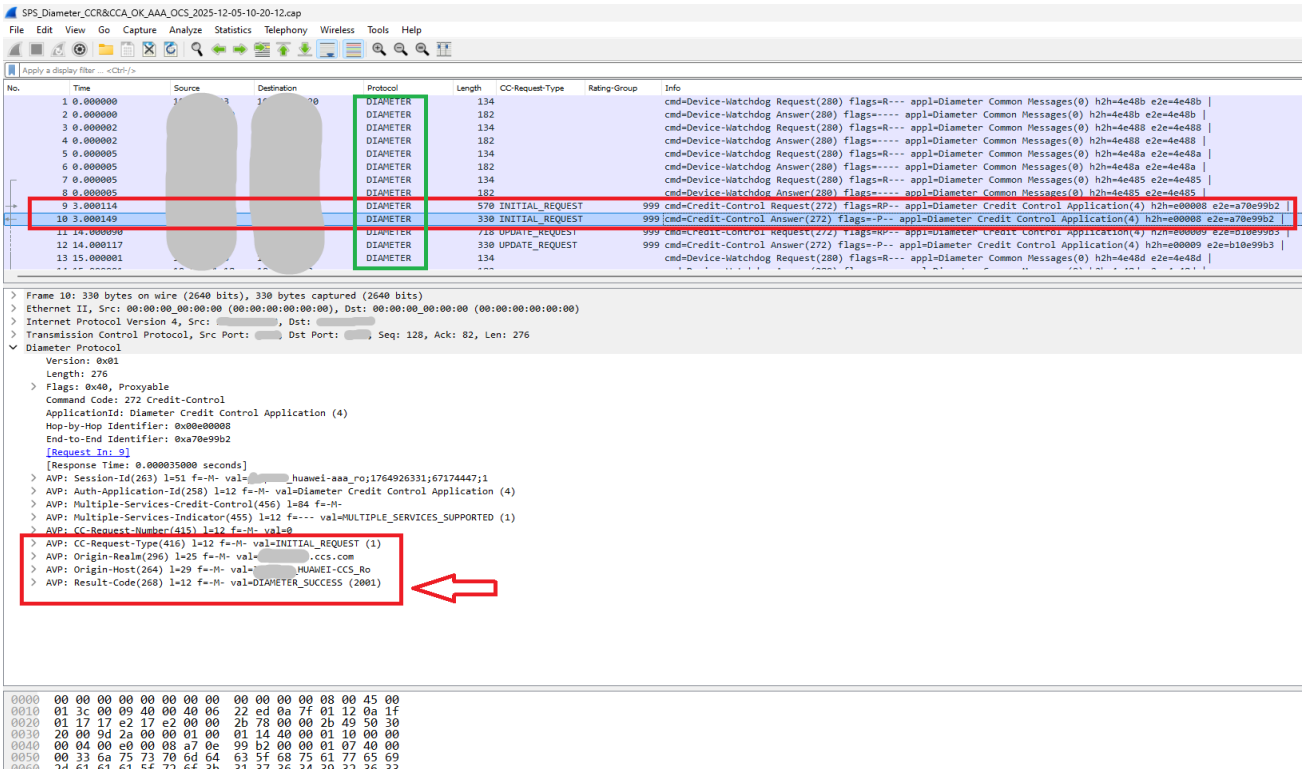

Figure 6: Screenshot from Diameter Success (2001)
Source: Captured by myself during real-world testing

17.2. Observed impacts between AAA and DRA

- No message from Capabilities -Exchange Request (257) / Capabilities -Exchange Answer (257);
- No proactive connectivity tests Device-Watchdog Request (280) / Device-Watchdog Answer (280)
- Credit -Control Request (272) / Credit Control Answer (272) sessions established ;
- Time lost due to potential incompatibilities during integration;
- Project manager frustration due to long integration delays.

17.3. Implemented Solutions

The solutions implemented consist of performing tests from AAA and collecting traces simultaneously at the AAA, DRA and CCS/OCS levels.

- Wireshark trace collection and analysis ;

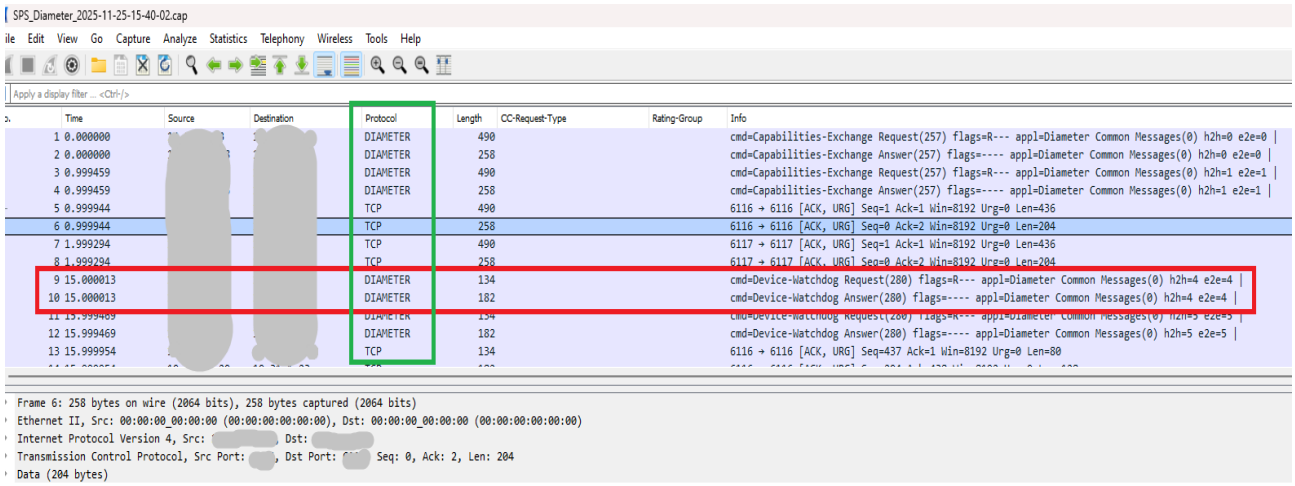

Figure 7: Screenshot from Diameter Success (2001)

Source: Captured by myself during real-world testing

– Review of messages and causes of errors

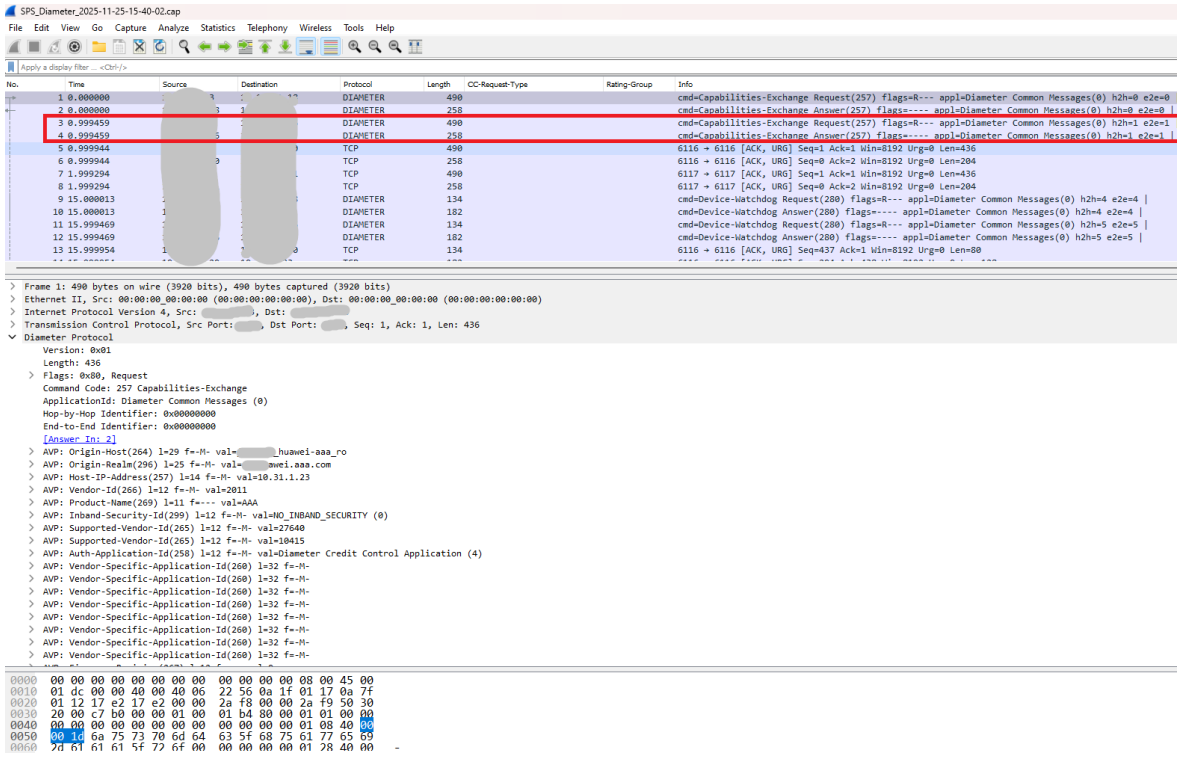

Figure 8: Screenshot from Diameter Success (2001)

Source: Captured by myself during real-world testing

– Review of routing tables and realms ;

– Synchronization of AAA, DRA and OCS configurations.

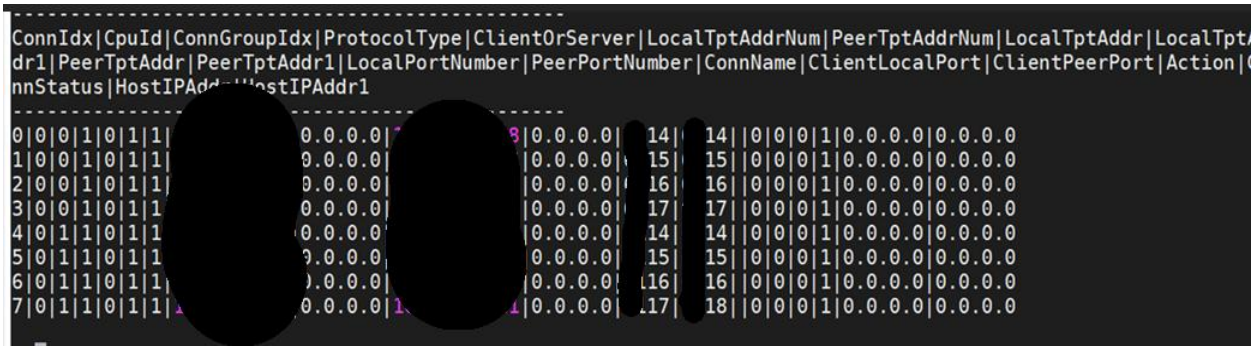

Figure 9: Screenshot of established connections Huawei-AAA server and DRA
Source: Huawei engineers - AAA

- Deployment of a proactive error monitoring mechanism for Diameter.

17.4. Comparison with previous work.

Previous studies on Diameter signaling and error handling in AAA-DRA-OCS architectures have primarily focused on protocol robustness and standards compliance. For example, Tschofenig et al. (2019) described Diameter as a major evolution from RADIUS, but without detailing the specific mechanisms for reducing 3002 and 3003 errors during the integration of new AAA servers. Their approach remains theoretical and focused on protocol design.

The recommendations from Nokia (2023) and Oracle (2024) offer practical solutions, such as adjusting Diameter timers and configuring routes, but they are often limited to troubleshooting guides without providing a comprehensive methodology for proactive optimization. These documents emphasize the need to verify attribute consistency (Destination-Realm, Destination-Host), which aligns with our hypothesis H1, but they do not address the adaptive dimension of routing policies.

Telcovas (2023) , for its part, highlights the strategic role of the DRA in the resilience of Diameter architectures, emphasizing the importance of realm- based routing policies . However, this approach does not explicitly address the issue of frequent errors on the Ro interface during AAA integrations, nor the impacts on service continuity.

Finally, 3GPP (2025), in the TS 32.299 specification, defines Ro flows and CCR/CCA messages, but without providing operational recommendations for reducing routing errors. This confirms that our study fills a gap by proposing an integrated approach: root cause diagnosis, route optimization, attribute normalization, and implementation of adaptive mechanisms.

17.5. Comparative Synthesis

- **Previous work** : Approaches focused on protocol compliance and ad-hoc troubleshooting (Nokia, Oracle, 3GPP).
- **Our contribution: A proactive and comprehensive methodology to reduce 3002/3003 errors, validated by** Wireshark traces adapted to multi-operator environments.

17.6. Originality of the work

This study stands out for its field approach with real traces, multi-level diagnostics (AAA, DRA, OCS) and complete validation of fixes in a production environment, which strengthens the operational value of the recommendations made.

The originality of this work lies in several key aspects:

17.7. Proactive and integrated approach

Unlike previous work which is limited to ad hoc recommendations or troubleshooting guides (Nokia, 2023; Oracle, 2024), this study proposes a complete methodology combining diagnosis, Diameter route optimization, attribute normalization (Destination-Realm, Destination-Host) and implementation of adaptive policies including the alignment of configuration parameters.

- **Focus on the RO interface during AAA integration** : Few studies specifically address errors 3002 and 3003 in the critical context of integrating a new AAA server. This work fills this gap by focusing on the impacts on real-time billing and service continuity.
- **wireshark traces :** The study is not limited to theoretical recommendations: it shares real wireshark traces and proposes an experimental protocol to evaluate the effectiveness of the solutions.
- **Alignment with standards and adaptation to the multi-operator context :** The proposed framework complies with IETF RFC 6733 and 3GPP TS 32.299 standards, while integrating operational constraints specific to multi-operator and high-load environments, which strengthens its practical relevance.

Discussion

The results confirm that errors 3002 and 3003 are primarily related to inconsistencies in the configuration of Diameter routes and attributes (Destination-Realm, Destination-Host), as well as the lack of alignment of the parameters " Attitude -Value-Pair (AVP) = Subscription -Id-Type" between OCS and AAA.

These observations align with the findings of recent work on the complexity of AAA-DRA-OCS architectures and the need for strict governance of Diameter attributes (Tschofenig et al., 2019; Nokia, 2023). This study is distinguished by its field-based approach, relying on concrete network traces and the validation of patches.

It highlights the importance of clear governance of exchanged data and ongoing communication between the engineers responsible for integration.

However, this work makes an original contribution by directly analyzing AAA/DRA/OCS logs and network captures on interface Ro, which made it possible to precisely locate the causes: mismatch between AAA and DRA on the configuration of the transport protocol SCTP instead of TCP and bad routing of the destination realms from the AAA server to CCS via DRA and, bad alignment of the AVP Subscription -Id-Type:END_USER_NAI (3) on the AAA side while OCS was using Subscription -Id-Type:END_USER_NAI (2).
Figure 10 below provides evidence.

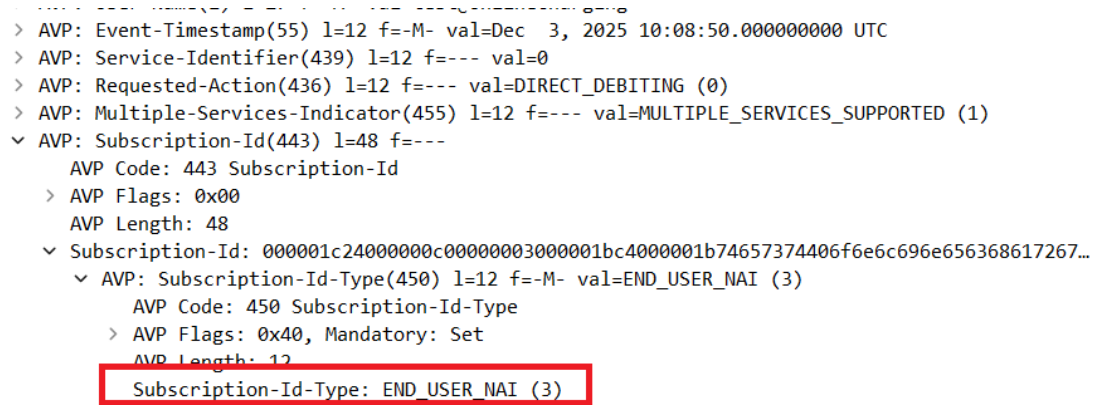

Figure 10: A Wireshark capture of the AVP subscription-Id-Type
Source: by myself during real-world testing

Unlike some previous studies that offer generic solutions, our approach is based on operational validation of the applied fixes: modification of static routing tables, restart of TCP connections , and alignment of Ro application services in each node.

And above all, to offer a resilient solution with priorities at the level of the Diameter (DMRT) protocol routing table.

Conclusion

The aim of this study was to answer the central question: *How to optimize AAA DRAOCS connectivity -to reduce DIAMETER_REALM_NOT_SERVED (3003) and DIAMETER_UNABLE_TO_DELIVER (3002) errors on the Ro interface when integrating a new AAA server?*

The analyses carried out made it possible to identify the major causes of these anomalies, mainly related to the lack of real communication between the two teams in charge of integration to the point where AAA configured SCTP while the configuration excel file had planned TCP, thus confirming the first hypothesis (**H1**).

The proposed experiments and recommendations, including the normalization of attributes and the optimization of routing tables (AAA should send the request to the OCS domain and not to the DRA domain), validate the second hypothesis (**H2**).

Finally, the optimization and alignment of the parameters " Attitude -Value-Pair (AVP) = Subscription -Id-Type" between OCS and AAA demonstrated their positive impact on the success of service tests, which confirms the third hypothesis (**H3**).

In summary, the joint optimization of routing parameters, Diameter attributes and the alignment of the parameters " Attitude -Value-Pair (AVP) = Subscription -Id-Type" constitutes an effective approach to guarantee the reliability of exchanges on the Ro interface.

These results provide operators with a robust operational framework to secure the integration of new AAA servers and improve the overall performance of Diameter architectures.

Perspectives

For future deployments, it is recommended to:

- Implement automatic validation tools for Diameter configurations.
- Strengthen the training of technical teams on the specifics of the RO interface.
- Emphasize communicating the parameters before any configuration to avoid potential errors.

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