A Smart Approach To Signalling Challenges On The Road To LTE

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Executive Summary

Over the past few years we have witnessed a radical shift in the way customers use mobile devices. The meteoric rise of the smartphone and resultant growth in data usage has forced mobile operators to continually evolve their mobile networks. This is taking place at a time when price competition in the market has never been more fierce, resulting in the introduction of more and more complex tariff plans. This is causing the mobile operators to place an increased focus on operating costs to optimise their spending.

Managing the massive growth in signalling, simplifying the maintenance activities, optimising and securing the signalling control plane are the challenges that mobile operators are facing today.

Approaching these challenges with the right tools and solutions is critical for mobile operators' success on the evolution to LTE.

Introduction

In this white paper we analyse the challenges mobile operators are facing today in the signalling control space as they upgrade to LTE and manage rapidly increasing mobile data consumption. We summarise the most common problems encountered and outline how the Diameter Signalling Controller and its logical functions can help mobile operators to overcome those challenges.

Operator Challenges

The growing use of mobile broadband dongles, smartphones and tablets on mobile networks is driving a massive increase in mobile data consumption. Mobile data and Internet traffic will grow at a CAGR of 66 % from 2012 to 2017 according to Cisco VNI Mobile 2013, reaching 11,157 Exabytes per Month by 2017.

Mobile Data and Internet Traffic, 2012 -2017

	2012	2013	2014	2015	2016	2017	CAGR 2012-2017
By Geography (TB) per Month)							
Asia Pacific	310,394	613,699	1,167,631	2,053,003	3,377,458	5,256,979	76%
Central and Eastern Europe	66,084	116,012	210,841	365,498	577,265	844,887	66%
Latin America	54,907	96,617	179,361	304,239	480,840	722,986	67%
Middle East and Africa	49,747	95,905	182,237	332,833	559,225	861,298	77%
North America	222,378	378,611	630,820	989,712	1,468,040	2,085,309	56%
Western Europe	181,397	276,405	426,152	655,201	975,681	1,384,072	50%
Total (TB per Month)							
Total Mobile Data Traffic	884,906	1,577,248	2,797,042	4,700,486	7,438,510	11,155,531	66%

Figure 1: Extracted from "Cisco VNI, 2013"

As data traffic grows exponentially, so too does the signalling traffic. This is one of the main challenges mobile operators face today. Signalling traffic growth has an impact on optimisation strategies for signalling routing, on the handling of the signalling traffic spikes and on the best approach to use when upgrading systems in the control plane.

In 4G networks, Diameter and SIP signalling replace traditional SS7 signalling. Diameter signalling is used for mobility and charging control while SIP is used for call and service control. Worryingly, Diameter signalling overload has already caused major outages for some operators. This has given rise to the term "Diameter Signalling Storm" and a growing demand from operators to deploy a solution to this problem.

In general, several factors contribute to the increase of signalling traffic:

- Smartphones generate significantly more signalling messages compared with feature phones;
- VoLTE, RCS and other services create additional signalling traffic on the core network;
- Real-time, online charging and advanced offerings (e.g., day passes) create new signalling traffic between operators' network elements in the control plane.

Mobile operators networks need to be ready to manage peaks in signalling traffic by introducing specific components, known as Diameter Signalling Controllers (DSC). The DSC can handle peaks of signalling traffic by manipulating the signalling message flow and distributing the load over multiple nodes, thereby protecting the other signalling components and the network overall from a Diameter Signalling overload.

In summary we can represent the main challenges and threats from the growth in data traffic with figure 2 below.

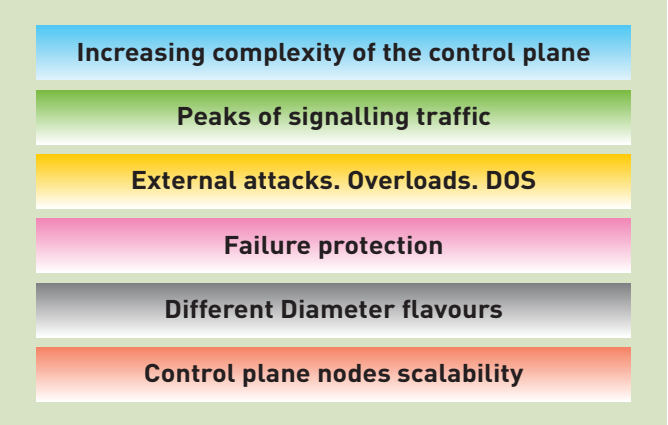

Figure 2: Challenges and threats

The consequences that these threats can generate are not to be underestimated. For this reason it is important to prepare the network to safely handle all these challenges.

The Diameter Signalling Controller

The DSC should provide the following primary capabilities to effectively manage and protect the signalling network:

- Centralisation of signalling routes;
- Conditional routing;
- Overload protection;
- Element failure protection;
- Protocol translation;
- AVP (Attribute Value Pairs) modifications and;
- Border signalling control

The DSC should include a set of logical functions that help to safely and smoothly face all of the challenges described in the previous section.

Figure 3: Logical functions of a Diameter Signalling Controller

In addition the DSC should have:

- A set of lower level functions to facilitate network configuration at IP and VLAN level;
- An internal logic based on robust algorithms that can handle peaks & overloads and identify nodes failures and poor performance;
- A flexible rules engine that makes it possible to create and apply rules or a group of rules to specific Diameter applications and specific network interfaces;
- An architecture that allows scaling of the DSC performance, simply and reliably.

The DSC is a critical node in the core network that has to be reliable and fully redundant. The DSC supports various use-cases and performs several critical roles.

The Most Common Use Cases

Centralised Routing

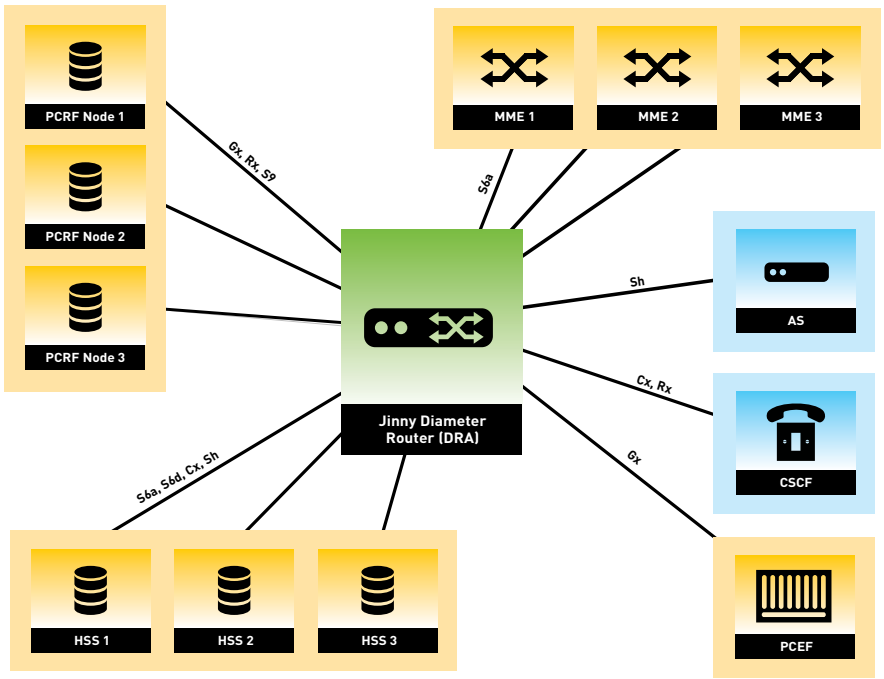

Figure 4: Signalling routing centralisation with a DRA

Using one or more DSCs in the core network to centralise the signalling traffic is a good way to simplify the topology of the control plane and reduce the time needed to introduce new nodes and maintain the existing ones. The main advantage of a centralised DSC is the facilitation of configuration and the reconfiguration when signalling components are added or removed. Another advantage is the ability to add/modify/remove AVPs (for instance in case of incompatibilities between nodes of different vendors that use different flavours of Diameter).

The DSC also protects specific nodes from signalling overload that could happen in specific situations such as a popular OTT service failure where clients lose connection and then a spike of clients simultaneous reconnection when the servers are up again. Another case is when parts of the mobile access network fail and then recover, triggering the "attach" procedure of many mobile terminals at the same time. In these cases, prioritisation and overload protection, managed by the Diameter Router, will help protect both the HSS and the PCRF nodes.

LTE Roaming

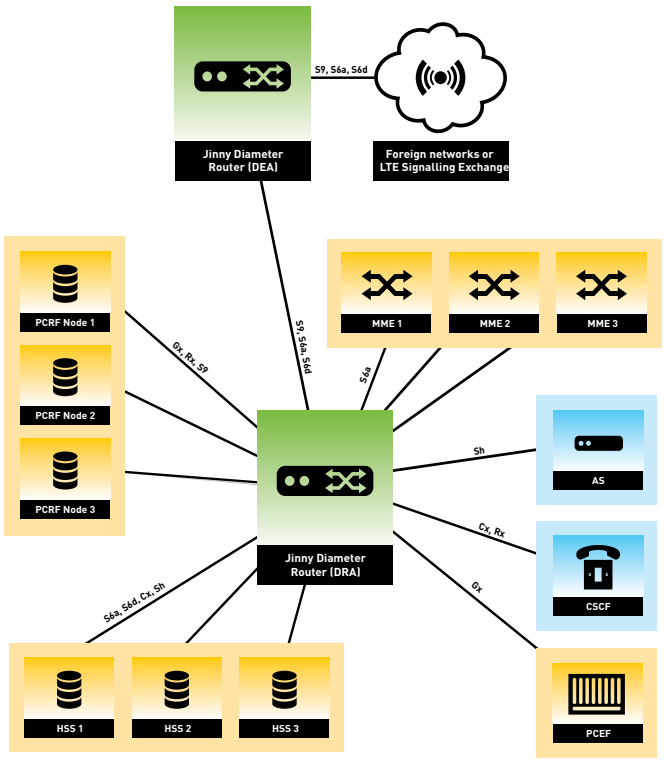

Figure 5: Signalling exchange between the home network and foreign networks using a DEA

Providing mobile communication services to one's own subscribers when they are roaming abroad is a key service in the modern telecommunication era. This introduces some challenges that mobile operators have to approach in the right way so that QoS is appropriate and security is guaranteed.

GSMA released the LTE Roaming Guidelines (IR.88) about how Long Term Evolution (LTE) and Evolved Packet Core (EPC) networks can interwork in order to provide "Next Generation Mobile Network" capabilities when users roam onto a network different from their mobile home network.

"In order to support scalability, resilience and maintainability, and to reduce the export of network topologies, the use of a PMN-edge Diameter agent is strongly recommended."[1] The Diameter Edge Agent (DEA)"is considered as the only point of contact into and out of an operator's network at the Diameter application level."[2]

A DSC acting as a DEA can ensure that all the signalling communications between mobile networks are concentrated in a single border checkpoint through which it is possible, not only to ensure the secrecy of the internal network topology but also to inspect the AVPs (and where required modify that) to ensure full compatibility between different Diameter flavours supported by different Diameter agents.

1 GSM Association - "Official Document IR.88 - LTE Roaming Guidelines"
2 GSM Association - "Official Document IR.88 - LTE Roaming Guidelines"

LTE to GSM/UMTS roaming

Roaming between LTE and GSM/UMTS mobile networks requires signalling exchanges between home and the visited mobile network. LTE mobile networks use Diameter as the signalling protocol to manage their subscribers roaming procedures while GSM/UMTS networks use SS7/MAP.

An interworking function (IWF) in this case is required to translate between Diameter and MAP enabling roaming between LTE and GSM/UMTS networks.

The IWF can be located at the mobile network border within the DEA or it can be located and operated by the LTE Signalling Exchange hub.

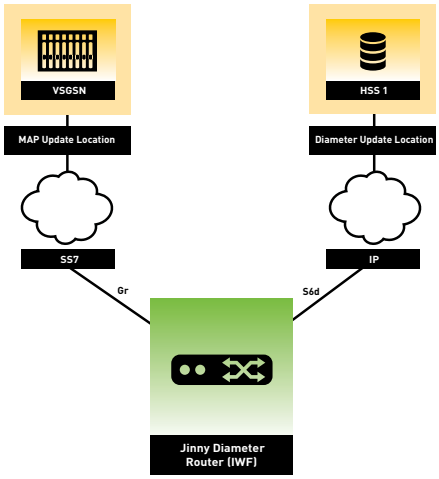

Figure 6: Signalling exchange between the home network and a foreign legacy network using the IWF part of the DEA

However, in both cases this functionality is required to enable roaming between LTE and legacy networks.

HSS address resolution

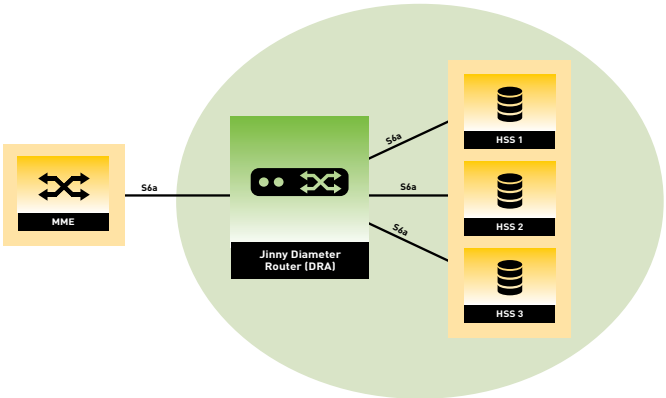

Figure 7: The DRA routes the Diameter messages from the MME to the correct HSS node using conditional routing

Sometimes when in a mobile network there are multiple HSS nodes a Subscriber Location Function (SLF) is required to route the subscription and authentication related Diameter messages to the HSS node where the specific subscriber is homed. Configuring the DSC interfaces with the appropriate rules enables the DSC to route the Diameter messages over the S6a interface to the correct HSS node.

The routing can be based on any command and AVP that is available (for instance it could be the IMSI or the MSISDN) on the S6a Diameter interface.

PCRF load balancing and binding

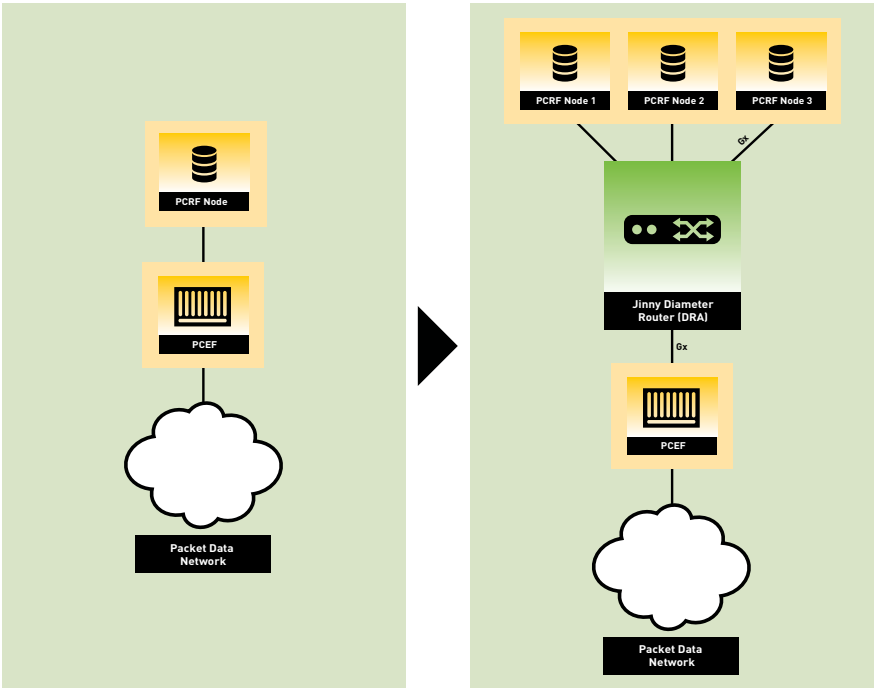

Figure 8: Scaling the PCRF using a DRA

The PCRF is the Policy and Charging Rules Function of the Policy Charging and Control (PCC) subsystem. It exchanges flow based charging control information over Rx with the CSCF as well as information over Gx with the PCEF. If a Bearer Binding and Reporting Function (BBERF) is used, the PCRF also exchanges information via Gxa/Gxc reference points.

In large mobile networks it is common to have multiple PCRF nodes connected to the PCEF/PDN GW over the Gx interface and to the AF/CSCF over the Rx interface.

In order to ensure that the same PCRF node is selected for all sessions that make up an IP-CAN session, a logical functional entity called the Diameter Routing Agent (DRA) is used during the selection discovery of the PCRF.

Even if some PCEF nodes can do it without an external DRA, this is not the best approach in terms of flexibility, scalability and ease of maintenance.

Positioning a DSC as a DRA between the PCEF and the PCRF on the Gx interface enables the distribution of Diameter messages statically or dynamically across multiple PCRF nodes and will also facilitate the replacement/addition/removal of nodes, when needed, avoiding complex reconfigurations.

The DSC should also enable the support of more complex cases where message routing can be conditional upon profiled groups of subscribers, provisioned into the system database.

OCS load balancing

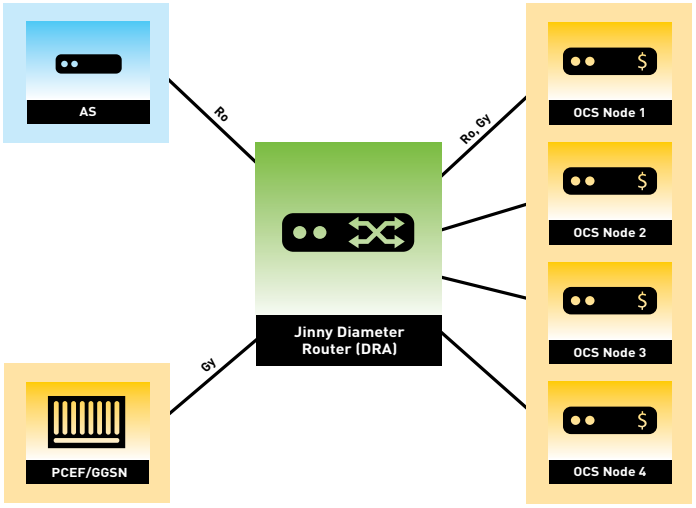

Figure 9: Distributing Diameter CCRs to a pool of OCS nodes

Sometimes mobile operators need to run multiple Online Charging System (OCS) nodes. For instance, when a specific node or a system is close to the capacity limit it is not always possible to upgrade it. In this case having additional OCS nodes is not unusual. A DSC simplifies the management of Diameter routing to multiple OCS nodes or systems.

The Operator can define routing tables on the DSC that dynamically share the load across a pool of OCS nodes, using various algorithms. It is possible to create static routes between specific platforms and specific OCS nodes/systems or conditional routing based on any AVP and command.

This approach gives the advantage of having a single point of management and control for the routing of Diameter messages to the OCS nodes.

Any modification or a node failure or replacement does not affect the service continuity as any node can be put offline and Diameter messages routed to another node without service interruption. When the node is restored the Diameter messages can be rerouted back to the restored node.

In this case like in other cases, a DSC can simplify the signalling routing, facilitate the maintenance and reduce the operating costs for the mobile operator.

Smart Caching

With Smart Caching, a special feature available of the Jinny Diameter Router, it is possible to cache any operation that doesn't cause a change in the target node. This opens up a range of opportunities to manage some specific scenarios and at the same time to offload the target node.

Offloading the target node can often translate to savings in terms of node license costs.

Caching query requests targeted to the HSS or to the OCS makes it possible to reduce the number of transactions the target node has to process. At the same time keeping the "time-to-live" parameter small enough will reduce the risk of getting out-dated information. For the applications in which the information must always be updated if the cache is used, it is possible to refresh the cache in real time, integrating the external source of the information with the Diameter Router using a HTTP/XML API.

There are many cases and different types of solutions to adapt Diameter Router smart caching to specific use cases. In all these cases filtering different types of queries using specific AVPs will relieve the target nodes from large amounts of transactions.

A typical example is the "daily pass". A mobile operator's subscriber normally purchases a daily pass through SMS, web portal or the call centre. Then the transaction is charged to the subscriber's account. This normally happens using an ecommerce application. After the purchasing phase he or she may be granted the right to send SMS messages for the next 24 hours.

In order to avoid the scenario where charging requests triggered by the SMSC reach the IN each time the subscriber sends a SMS within the daily pass validity period, the Diameter Router, being a Diameter proxy, can proxy these charging requests using the subscriber's MSISDN, discard them and send back an ACK to the SMSC that will deliver the SMS message to the destination.

The ecommerce application using the Diameter API shall only provision the subscriber's MSISDN to the Diameter Router database with the duration of the pass.

The advantage of this approach is clearly to offload the OCS by an amount of transactions that are not really remunerative or useful.

A Versatile Diameter Agent

The Jinny Diameter Router is the most efficient approach to address various problems that otherwise would require complex solutions or that could not be resolved at all.

Having all the tools in a single platform is very useful to streamline and optimise the control plane design or simply to fix single issues.

Consolidating and centralising the signalling for the core network generates savings in the operational costs.

In this context the Jinny Diameter Router can be deployed in different ways.

There are two main approaches to consider:

- Consolidating all the signalling in a single Jinny Diameter Router cluster
- Using multiple clusters to handle signalling of different subsystems

Usually the first approach is common in tier 3 mobile operators. In this case configuring the DRA to handle the entire or most of the Diameter signalling is possible and cost effective. However a dedicated DEA for the roaming signalling exchange is always considered to be a best practice.

Alternatively, tier 1 mobile operators prefer to allocate dedicated clusters to handle the signalling of specific subsystems. As an example one could have a DRA to load balance the signalling in the PCC subsystem, another DRA to manage authentication and location updates in front a pool of HSS nodes and others to consolidate signalling in other portions of the control plane. A dedicated DEA cluster is also needed to manage the signalling between the mobile operator and its roaming partners including LSX hub as per GSMA guidelines (IR.88).

Conclusions

Signalling routing has always been a complex and critical matter. It is even more so today where the complexity of the new networks and the boom of mobile data and mobile Internet consumption has introduced greater risks.

In this white paper we've tried to analyse the most common risks and use cases that justify the deployment of one or more DSCs in a mobile network with the scope to help mobile operators simplifying their signalling routing, securing interconnections and protecting the control plane from overloads and network element failure consequences.

We've tried also to explain how a DSC in the network can help to increase the operational flexibility in day-to-day tasks, saving time and reducing the risks of mistakes.

This white paper does not claim to cover all cases and scenarios but only to give an overview of the most interesting cases in which a DSC can be really useful.

Jinny Software have engineered and developed a DSC called Jinny Diameter Router that helps mobile operators to address all the cases described in this white paper plus many others in an easy and efficient way.

Annexes

Annex A - Main Diameter interfaces

Cx	Between I-CSCF/S-CSCF and the HSS
Sh	Used between AS and HSS
Rf	Used to exchange offline charging information with CDF
Ro	Used to exchange online charging information with OCF
Gx	Used to exchange policy decisions-related information between PCEF and PCRF
Gxx	Between BBERF and PCRF (Gxa and Gxc)
Rx	Used to exchange policy and charging related information between the Application Function and the Policy and Charging Rule Function
S6a	Used between MME and HSS
S6d	Used between the SGSN and the HSS
S13	The 3GPP S13/S13' enables the Mobile Equipment Identity check procedure between the Mobile Management Entity (MME) and the Equipment Identity Register (EIR) on the S13 interface and between the Serving GPRS Support Node (SGSN) and the Equipment Identity Register (EIR) on the S13' interface
S9	Interface between hPCRF and vPCRF in a roaming scenario
Gy	Interface between PCEF and OCS

Annex B - Terms and abbreviations

AF	Application Function
API	Application Protocol Interface
AVP	Attribute Value Pairs
BBERF	Bearer Binding and Event Reporting Function
CDF	Charging Data Function
DCCA	Diameter Credit Control Application
DEA	Diameter Edge Agent
DLB	Diameter Load Balancer
DRA	Diameter Routing Agent
DSC	Diameter Signalling Controller
EIR	Equipment Identity Register
GSMA	GSM Association
GUI	Graphical User Interface
HSS	Home Subscriber Server
HTTP	Hypertext Transfer Protocol
I-CSCF	Interrogating Call Session Control Function
P-CSCF	Proxy Call Session Control Function
S-CSCF	Serving Call Session Control Function
LSX	LTE Signalling Exchange
MME	Mobility Management Entity
OCF	Online Charging Function
OCS	Online Charging System
OTT	Over The Top
PCEF	Policy and Charging Enforcement Function
PCRF	Policy and Charging Rules Function
SMS	Short Message Service
XML	Extensible Markup Language

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