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**PASSporT Extension for Diverted Calls  
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Abstract

PASSporT is specified in [RFC 8225](#) to convey cryptographically-signed information about the people involved in personal communications. This document extends PASSporT to include an indication that a call has been diverted from its original destination to a new one. This information can greatly improve the decisions made by verification services in call forwarding scenarios. Also specified here is an encapsulation mechanism for nesting a PASSporT within another PASSporT that assists relying parties in some diversion scenarios.

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## 1. Introduction

A Personal Assertion Token (PASSport [\[RFC8225\]](#)) is a token format based on the JSON Web Token (JWT [\[RFC7519\]](#)) for conveying cryptographically-signed information about the people involved in personal communications; it is used by the Secure Telephone Identity Revisited (STIR [\[RFC8224\]](#)) protocol to convey a signed assertion of the identity of the participants in real-time communications established via a protocol like SIP. This specification extends PASSport to include an indication that a call has been diverted from its original destination to a new one.

Although the STIR problem statement [\[RFC7340\]](#) is focused on preventing the impersonation of the caller's identity, which is a common enabler for threats such as robocalling and voicemail hacking on the telephone network today, it also provides a signature over the called number at the time that the authentication service sees it.

As [\[RFC8224\] Section 12.1](#) describes, this protection over the contents of the To header field is intended to prevent a class of cut-and-paste attacks. If Alice calls Bob, for example, Bob might attempt to cut-and-paste the Identity header field in Alice's INVITE into a new INVITE that Bob sends to Carol, and thus be able to fool Carol into thinking the call came from Alice and not Bob. With the signature over the To header field value, the INVITE Carol sees will clearly have been destined originally for Bob, and thus Carol can view the INVITE as suspect.

However, as [\[RFC8224\] Section 12.1.1](#) points out, it is difficult for Carol to confirm or reject these suspicions based on the information she receives from the baseline PASSporT object. The common "call forwarding" service serves as a good example of the reality that the original called party number is not always the number to which a call is delivered. There are a number of potential ways for intermediaries to indicate that such a forwarding operation has taken place. The address in the To header field value of SIP requests is not supposed to change, according to baseline SIP behavior

[\[RFC3261\]](#); instead, it is the Request-URI that is supposed to be updated when a call is retargeted. Practically speaking, however, many operational environments do alter the To header field. The History-Info header field [\[RFC7044\]](#) was created to store the Request-URIs that are discarded by a call in transit. The SIP Diversion header field [\[RFC5806\]](#), though historic, is still used for this purpose by some operators today. Neither of these header fields provide any cryptographic assurance of secure redirection, and they both record entries for minor syntactical changes in URIs that do not reflect a change to the actual target of a call.

This specification therefore extends PASSporT with an explicit indication that the original called number in PASSporT no longer reflects the destination to which a call is intended to be delivered.

For this purpose, it specifies a "div" PASSporT type for use in common SIP retargeting cases; it is expected that in this case, SIP INVITE requests will carry multiple Identity header fields, each containing its own PASSporT. Throughout this document, PASSporTs that contain a "div" element will be referred to as "div" PASSporTs. Verification services and the relying parties who make authorization decisions about communications may use this diversion indication to confirm that a legitimate retargeting of the call has taken place, rather than a cut-and-paste attack. For out-of-band [\[I-D.ietf-stir-oob\]](#) use cases, and other non-SIP applications of PASSporT, a separate "div-o" PASSporT type is also specified, which defines an "opt" PASSporT element for carrying nested PASSporTs within a PASSporT. These shall in turn be referred to in this document as "div-o" PASSporTs.



## **2. Terminology**

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in

[BCP](#)

[14](#) [[RFC2119](#)] [[RFC8174](#)] when, and only when, they appear in all capitals, as shown here.

## **3. The 'div' PASSporT Type and Claim**

This specification defines a PASSporT [[RFC8225](#)] type called "div" that may be employed by authentication services located at retargeting entities. All "div" PASSporTs MUST contain a new JSON Web Token "div" claim, also specified in this document, which indicates a previous destination for a call during its routing process. When a retargeting entity receives a call signed with a PASSporT, it may act as an authentication service and create a new PASSporT containing the "div" claim to attach to the call. Note

that

a new PASSporT is only necessary when the canonical form of the "dest" identifier (per the canonicalization procedures in [[RFC8224](#)] [Section 8](#)) changes due to this retargeting. If the canonical form

of

the "dest" identifier is not changed during retargeting, then a new PASSporT with a "div" claim MUST NOT be produced. The headers of

the

new PASSporTs generated by retargeting entities MUST include the "div" PASSporT type, and an "x5u" field pointing to a credential

that

the retargeting entity controls. "div" PASSporTs MUST use full form instead of compact form. The new PASSporT header will look as follows:

```
{ "typ":"passport",  
  "ppt":"div",  
  "alg":"ES256",  
  "x5u":"https://www.example.com/cert.cer" }
```

A "div" PASSporT claims set is populated with elements drawn from the

PASSporT(s) received for a call by the retargeting entity: at a high level, the original identifier for the called party in the "dest" object will become the "div" claim in the new PASSporT. If the "dest" object of the original PASSporT contains multiple

identifiers,

because it contains one or more name/value pairs with an array as

its

value, the retargeting entity MUST select only one identifier from the value(s) of the "dest" object to occupy the value of the "div" field in the new PASSporT. Moreover, it MUST select an identifier that is within the scope of the credential that the retargeting

entity will specify in the "x5u" of the PASSport header (as described below).

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the ordinary construction of a PASSport, the credential used to sign

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will have authority over the identity in the "orig" claim (for example, a certificate with authority over the telephone number in "orig" per [\[RFC8226\]](#)), for all PASSporTs using the "div" type the signature MUST be created with a credential with authority over the identity present in the "div" claim. So for the example above, where the original "dest" is "12155551213", the signer of the new PASSporT object MUST have authority over that telephone number, and need not have any authority over the telephone number present in the "orig" claim.

Note that Identity header fields are not ordered in a SIP request, and in a case where there is a multiplicity of Identity header fields in a request, some sorting may be required to match "div" PASSporTs to their originals.

PASSporTs of type "div" MUST NOT contain an "opt" (see [Section 6](#)) element in their payload.

#### **4. Using 'div' in SIP**

This section specifies SIP-specific usage for the "div" PASSporT type and its handling in the SIP Identity header field "ppt" parameter value. Other using protocols of PASSporT may define behavior specific to their use of the "div" claim.

##### **4.1. Authentication Service Behavior**

An authentication service only adds an Identity header field value containing the "div" PASSporT type to a SIP request that already contains at least one Identity header field value; it MUST NOT add a "div" PASSporT to an INVITE that contains no Identity header field. The retargeting entity SHOULD act as a verification service and validate the existing Identity header field value(s) in the request before proceeding; in some high-volume environments, it may instead put that burden of validating the chain entirely on the terminating verification service. As the authentication service will be adding a new PASSporT that refers to an original, it MUST NOT remove the original request's Identity header field value before forwarding.

As was stated in [Section 3](#), the authentication service MUST sign any "div" PASSporT with a credential that has a scope of authority covering the identity it populates in the "div" element value. Note that this is a significant departure from baseline STIR authentication service behavior, in which the PASSporT is signed by a credential with authority over the "orig" field. The "div" value reflects the URI that caused the call to be routed to the retargeting

entity, so in ordinary operations, it would already be the STIR

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that need to be performed at verification services.

Furthermore, a request may also be retargeted a second time, at which point the subsequent retargeting entity SHOULD generate one "div" PASSport for each previous "div" PASSport in the request which contains a "dest" object with the value of the current target - but

not for "div" PASSporTs with earlier targets. Ordinarily, the current target will be readily identifiable, as it will be in the last "div" PASSporT in each chain, and in SIP cases it will correspond to the Request-URI received by the retargeting entity. Moreover, the current target will be an identifier that the retargeting entity possess a credential to sign for, which may not be true for earlier targets. Ultimately, on each retargeting, the number of PASSporTs added to a request will be equal to the number of non-"div" PASSporTs that do not share the same "orig" and "dest" object values.

#### **4.2. Verification Service Behavior**

[RFC8224] [Section 6.2](#) Step 5 requires that specifications defining "ppt" values describe any additional or alternative verifier behavior. The job of a SIP verification service handling one or more

"div" PASSporTs is very different from that of a traditional verification service. At a high level, the immediate responsibility of the verification service is to extract all PASSporTs from the two or more Identity header fields in a request, identify which are "div" PASSporTs and which are not, and then order and link the "div" PASSporTs to the original PASSporT(s) in order to build one or more chains of retargeting.

In order to validate a SIP request using the "div" PASSporT type, a verification service needs to inspect all of the valid Identity header field values associated with a request, as an Identity header field value containing "div" necessary refers to an earlier PASSporT already in the message. For each "div" PASSporT, the verification service MUST find an earlier PASSporT that contains a "dest" claim with a value equivalent to the "div" claim in each "div" PASSporT. It is possible that this earlier PASSporT will also contain a "div", and that it will in turn chain to a still earlier PASSporT stored in a different Identity header field value. If a complete chain cannot be constructed, the verification service cannot complete "div" validation; it MAY still validate any non-"div" PASSporTs in the request per normal [\[RFC8224\]](#) procedures. If a chain has been successfully constructed, the verification service extracts from the outermost (that is, the most recent) PASSporT in the chain a "dest" field; this will be a "div" PASSporT that no other "div" PASSporT in the SIP request refers to. Its "dest" element value will be referred to in the procedures that follow as the value of the "outermost "dest" field."

Ultimately, by looking at this chain of transformations and validating the associated signatures, the verification service will be able to ascertain that the appropriate parties were responsible

for the retargeting of the call to its current destination. This  
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help the verification service to determine that the original PASSporT in the call was not simply used in a cut-and-paste attack and inform any associated authorization decisions in terms of how the call will be treated - though, per [\[RFC8224\] Section 6.2.1](#), that decision is a matter of local policy and is thus outside the scope of this specification. A verification service parses a chain of PASSporTs as follows:

First, the verification service MUST compare the value in the outermost "dest" field to the target of the call. As it is anticipated that SIP authentication services that create "div" PASSporTs will populate the "dest" header from the retargeted Request-URI (see [Section 4.1](#)), in ordinary SIP operations, the Request-URI is where verification services will find the latest call target. Note however that after a "div" PASSporT has been added to a SIP request, the Request-URI may have been updated during normal call processing to an identifier that no longer contains the logical destination of a call; in this case, the verification service MAY compare the "dest" field to a provisioned telephone number for the recipient.

Second, the verification service MUST validate the signature over the outermost "div" PASSporT, and establish that the credential that signed the "div" PASSporT has the authority to attest for the identifier in the "div" element of the PASSporT (per [\[RFC8224\] Section 6.2](#) Step 3).

Third, the verification service MUST validate that the "orig" field of the innermost PASSporT of the chain (the only PASSporT in the chain which will not be of PASSporT type "div") is equivalent to the "orig" field of the outermost "div" PASSporT; in other words, that the original calling identifier has not been altered by retargeting authentication services. If the "orig" value has changed, the verification service MUST treat the entire PASSporT chain as invalid. The verification service MUST also verify that all other "div" PASSporTs in the chain share the same "orig" value. Then the verification service validates the relationship of the "orig" field to the SIP-level call signaling per the guidance in [\[RFC8224\] Section 6.2](#) Step 2.

Fourth, the verification service MUST check the date freshness in the outermost "div" PASSporT per [\[RFC8224\] Section 6.2](#) Step 4. It is furthermore RECOMMENDED that the verification service check that the "iat" field of the innermost PASSporT is also within the date freshness interval; otherwise the verification service could allow attackers to replay an old, stale PASSporT embedded in a

fresh "div". However, note that in some use cases, including certain ways that blind transfer is implemented, it is possible

that an established call will be retargeted long after it has originally been placed, and verification services may want to allow a longer window for the freshness of the innermost PASSporT if the call is transferred from a trusted party.

Fifth, the verification service MUST inspect and validate the signatures on each and every PASSporT object in the chain between the outermost "div" PASSporT and the innermost PASSporT. Note that (per [Section 4.1](#)) a chain may terminate at more than one innermost PASSporT, in cases where a single "div" is used to retarget from multiple innermost PASSporTs. Also note that [\[RFC8224\] Section 6.2](#) Step 1 applies to the chain validation process: if the innermost PASSporT contains an unsupported "ppt", its chain MUST be ignored.

Note that the To header field is not used in the first step above. Optionally, the verification service MAY verify that the To header field value of the received SIP signaling is equal to the "dest" value in the innermost PASSporT; however, as has been observed in some deployments, the original To header field value may be altered by intermediaries to reflect changes of target. Deployments that change the original To header field value to conceal the original destination of the call from the ultimate recipient should note that the original destination of a call may be preserved in the innermost PASSporT. Future work on "div" might explore methods to implement that sort of policy while retaining a secure chain of redirection.

## **5. The 'div-o' PASSporT Type**

This specification defines a "div-o" PASSporT type that uses the "div" claim element in conjunction with the opt ([Section 6](#)) PASSporT claim element. As is the case with "div" PASSporT type, a "div-o" PASSporT is created by an authentication service acting for a retargeting entity, but instead of generating a separate "div" PASSporT to be conveyed alongside an original PASSporT, the authentication service in this case embeds the original PASSporT inside the "opt" element of the "div-o" PASSporT. The "div-o" extension is designed for use in non-SIP or gatewayed SIP environments where the conveyance of PASSporTs in separate Identity header fields is impossible, such as out-of-band [\[I-D.ietf-stir-oob\]](#) STIR scenarios.

The syntax of "div-o" PASSporTs is very similar to "div". A "div-o" PASSporT header object might look as follows:





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```
Identity:eyJhbGciOiJFUzI1NiIsInBwdCI6ImRpdj1vIiwidHlwIjoicGFzc3Bvc
\
nQiLCJ4NXUiOiJodHRwczovL3d3dy5leGFtcGxlLmNvbS9jZXJ0LmNlciJ9.eyJkZX
\
N0Ij7InRuIjoiMTIxNTU1NTEyMTQifSwiZGl2Ij7InRuIjoiMTIxNTU1NTUxMjEz
\
In0sImhhdCI6MTQ0MzIwODM0NSwib3B0IjoiZXlKaGJHY2lPaUpGVXpJMU5pSXNjb1
\
I1Y0NjNkluQmhmjM053YjNKMElpd2llRFYxSwpvawFIUjBjSE02THk5M2QzY3VaWgho
\
YlhCc1pTNWpiMjB2WTJWewRDNWpawElpZlEuZXlKa1pYTjBJanA3SW5SdUlqcGJJak
\
V5TVRVMU5UVXhNakV6SWwxOUxDSnBZWFFpT2pFME5ETXlNRGd6TkrVc0ltOXlhV2Np
\
T25zaWRHNGlPaUl4TWpFMU5UVTFNVEl4TWlKOWZRLjFiRXpremNOYkt2Z3o0UW9NeD
\
BfREoyVDhxRk1EQzFzUHFUFIUfHsMVd2YmF1e1JKUnZZbFpxUTBxZ0dUbFM4dEpfd1hq
\
VmUwN1ozd3ZEcMRCeHoaFl3Iiwib3JpZyI6eyJ0biI6IjEyMTU1NTUxMjEzIn19.C
\
HeA9wRnthl7paMe6rP0TARpmFCXjmi_vF_HRz20_oulB_R-G9xZNiLVvmvHv4gk6LI
\
LaDV2y2VtHTLIEgmHig; \
info=<https://www.example.com/cert.cer>;ppt="div-o"
```

The authentication and verification service procedures required for "div-o" will necessarily be specific to the protocol or environment where it is used, and thus are left to future work.

## **6. Definition of 'opt'**

The presence of an original PASSport claims set element, designated as "opt", signifies that a PASSport encapsulates another entire PASSport within it, typically a PASSport that was transformed in some

way to create the current PASSport. Relying parties may need to consult the encapsulated PASSport in order to validate the identity of a caller. "opt" as defined in this specification may be used by future PASSport extensions as well as in conjunction with "div-o".

"opt" MUST contain a quoted base64 encoded full-form PASSport as specified by [\[RFC8225\] Appendix A](#); it MUST NOT contain a compact form

PASSport. For an example of a "div-o" PASSport containing "opt," see

[Section 5](#).

## **7. 'div' and Redirection**

The "div" mechanism exists primarily to prevent false negatives at verification services when an arriving SIP request, due to intermediary retargeting, does not appear to be intended for its

eventual recipient, because the original PASSport "dest" value designates a different destination.

Any intermediary that assigns a new target to a request can, instead of retargeting and forwarding the request, instead redirect with a 3xx response code. In ordinary operations, a redirection poses no difficulties for the operations of baseline STIR: when the user agent client (UAC) receives the 3xx response, it will initiate a new request to the new target (typically the target carried in the Contact header field value of the 3xx), and the "dest" of the



PASSporT created for the new request will match that new target. As no impersonation attack can arise from this case, it creates no new requirements for STIR.

However, some UACs record the original target of a call with mechanisms like History-Info [[RFC7044](#)] or Diversion [[RFC5806](#)], and may want to leverage STIR to demonstrate to the ultimate recipient that the call has been redirected securely: that is, that the original destination was the one that sent the redirection message that led to the recipient receiving the request. The semantics of the PASSporT necessary for that assertion are the same as those for the "div" retargeting cases above. The only wrinkle is that the PASSporT needs to be generated by the redirecting entity and sent back to the originating user agent client within the 3xx response.

This introduces more complexity than might immediately be apparent. In the first place, a 3xx response can convey multiple targets through the Contact header field value; to accommodate this, the "div" PASSporT MAY include one "dest" object array value per

Contact,

but if the retargeting entity wants to keep the Contact list private from targets, it may need to generate one PASSporT per Contact.

Bear

in mind as well that the original SIP request could have carried multiple Identity header field values that had been added by different authentication services in the request path, so a redirecting entity might need to generate one "div" PASSporT for

each

PASSporT in the original request. Often, this will mean just one "div" PASSporT, but for some deployment scenarios, it could require an impractical number of combinations. But in very complex call routing scenarios, attestation of source identity would only add limited value anyway.

STIR-aware SIP intermediaries that redirect requests MAY therefore convey one or more PASSporTs in the backwards direction within Identity header fields. These redirecting entities will act as authentication services for "div" as described in [Section 4.1](#). This document consequently updates [[RFC8224](#)] to permit carrying Identity header fields in SIP 300-class responses. It is left to the originating user agent to determine which Identity header fields should be copied from the 3xx into any new requests resulting from the redirection, if any: use of these Identity header fields by entities receiving a 3xx response is OPTIONAL.

Finally, note that if an intermediary in the response path consumes the 3xx and explores new targets itself while performing sequential forking, it will effectively retarget the call on behalf of the redirecting server, and this will create the same need for "div" PASSporTs as any other retargeted call. These intermediaries MAY



also copy PASSporTs from the 3xx response and insert them into sequential forking requests, if appropriate.

## **8. Extending 'div' to work with Service Logic Tracking**

It is anticipated that "div" may be used in concert with History-Info

[[RFC7044](#)] in some deployments. It may not be clear from the "orig" and "dest" values which History-Info header a given PASSporT correlates to, especially because some of the target changes tracked by History-Info will not be reflected in a "div" PASSporT (see [Section 1](#)). Therefore an "hi" element as defined here may appear in "div" corresponding to the History-Info header field index parameter value. So for a History-Info header field with an index value of "1.2.1", the claims set of the corresponding PASSporT with "div" might look like:

```
{ "orig":{"tn":"12155551212"},  
  "dest":{"tn":["12155551214"]},  
  "iat":1443208345,  
  "div":{"tn":"12155551213",  
        "hi":"1.2.1"} }
```

Past experience has shown that there may be additional information about the motivation for retargeting that relying parties might consider when making authorization decisions about a call, see for example the "reason" associated with the SIP Diversion header field [[RFC5806](#)]. Future extensions to this specification might incorporate reasons into "div".

## **9. Acknowledgments**

We would like to thank Ning Zhang, Dave Hancock, Chris Wendt, Sean Turner, Russ Housley, Ben Campbell, Eric Burger, and Robert Sparks for contributions to this document.

## **10. IANA Considerations**

This document contains actions for the IANA.

### **10.1. JSON Web Token Claims Registrations**

This specification requests that the IANA add two new claims to the JSON Web Token Claims registry as defined in [[RFC7519](#)].



### **10.1.1. 'div' registration**

Claim Name: "div"

Claim Description: New Target of a Call

Change Controller: IESG

Specification Document(s): [RFCThis]

### **10.1.2. 'opt' registration**

Claim Name: "opt"

Claim Description: Encapsulated JSON token

Change Controller: IESG

Specification Document(s): [RFCThis]

## **10.2. PASSporT Type Registrations**

This specification defines two new PASSporT types for the PASSport Extensions Registry defined in [RFC8225], which resides at <https://www.iana.org/assignments/passport/passport.xhtml#passport-extensions>. They are:

"div" as defined in [RFCThis] [Section 3](#).

"div-o" as defined in [RFCThis] [Section 5](#).

## **11. Privacy Considerations**

There is an inherent trade-off in any mechanism that tracks in SIP signaling how calls are routed through a network, as routing decisions may expose policies set by users for how calls are forwarded, potentially revealing relationships between different identifiers representing the same user. Note however that in ordinary operations, this information is revealed to the user agent service of the called party, not the calling party. It is usually the called party who establishes these forwarding relationships, and if indeed some other party is responsible for calls being forwarded to the called party, many times the called party should likely be entitled to information about why they are receiving these calls. However, as there may be unforeseen circumstances where the revelation of service logic to the called party poses a privacy risk, implementers and users of this or similar diversion-tracking techniques should understand the trade-off.



Furthermore, it is a general privacy risk of identity mechanisms overall that they do not interface well with anonymization services; the interaction of STIR with anonymization services is detailed in [\[RFC8224\] Section 11](#). Any forwarding services that acts as an anonymizing proxy may not be able to provide a secure chain of retargeting due to the obfuscation of the originating identity.

## **12. Security Considerations**

This specification describes a security feature, and is primarily concerned with increasing security when calls are forwarded. Including information about how calls were retargeted during the routing process can allow downstream entities to infer particulars of

the policies used to route calls through the network. However, including this information about forwarding is at the discretion of the retargeting entity, so if there is a requirement to keep the original called number confidential, no PASSporT should be created for that retargeting - the only consequence will be that downstream entities will be unable to correlate an incoming call with the original PASSporT without access to some prior knowledge of the policies that could have caused the retargeting.

Any extension that makes PASSporTs larger creates a potential amplification mechanism for SIP-based DDoS attacks. Since diversion PASSporTs are created as a part of normal forwarding activity, this risk arises at the discretion of the retargeting domain: simply using

3xx response redirections rather than retargeting (with supply a "div" per [Section 7](#)) mitigates the potential impact. Under unusual traffic loads, even domains that might ordinarily retarget requests can switch to redirection.

## **13. References**

### **13.1. Normative References**

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## Appendix A. Appendix A: Keys for Examples

The following EC256 keys are used in the signing examples given in this document. WARNING: Do not use this key pair in production systems.

```
-----BEGIN PUBLIC KEY-----
MFkwEwYHKoZIzj0CAQYIKoZIzj0DAQcDQgAEEmzGM1Vs0+3IqbMF54rQMaYKQft04
hUYm9wv5wutLgEd9FsiTy3+4+Wa207pff0XPC0Qz0+yD8hGEXGP/2mZo6w==
-----END PUBLIC KEY-----

-----BEGIN EC PRIVATE KEY-----
MHcCAQEEIFKCsFZ4Wsw3ZpBxgc4Z0s0jaXDdMk07Ny1fKg60ntAkoAoGCCqGSM49
AwEHoUQDQgAEEmzGM1Vs0+3IqbMF54rQMaYKQft04hUYm9wv5wutLgEd9FsiTy3+4
+Wa207pff0XPC0Qz0+yD8hGEXGP/2mZo6w==
-----END EC PRIVATE KEY-----
```

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