INTRODUCTION TO

# REST API Security

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## WHAT IS A RESTFUL API?

An Application Programming Interface (API) is a set of clearly defined methods of communication between various software components. A good API makes it easier to develop a computer program by providing all the building blocks. While the specifications vary between various APIs, the end goal is to provide value to the programmer through utilization of the services gained from using an API.

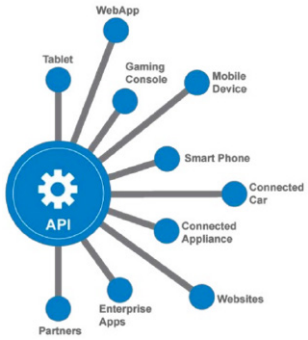
REST (or REpresentational State Transfer) is an architectural style that evolved as Fielding wrote the HTTP/1.1 and URI specs and has proven to be well-suited for developing distributed hypermedia applications. While REST is more widely applicable, it is most commonly used within the context of communicating with services via HTTP.

### WHY DOES SECURITY MATTER?

Security aspects should be a serious consideration when designing and deploying a RESTful API.

### ORGANIZATIONS UNDERSTAND THE NEED FOR API SECURITY

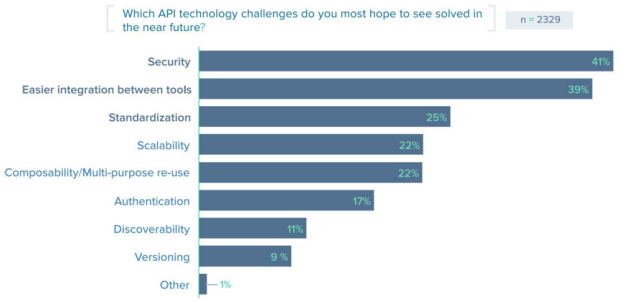
In today's connected world, where information is being shared via APIs to external stakeholders and within internal teams, security is a top concern.



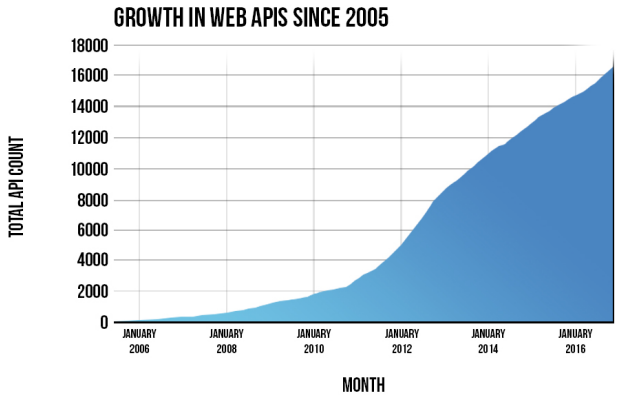

API security is the single biggest challenge organizations want to see solved in the years ahead, and solving the security challenge is expected to be a catalyst for growth in the API world.

According to research by SmartBear presented in their State of APIs Report 2016:

- Security is the #1 technology challenge teams want to see solved; 41.2% of respondents say security is the biggest API technology challenge they hope to see solved.
- Security is the #4 technology area expected to drive the most API growth in the next two years; 24% of API providers say digital security will drive the most API growth in the next two years.
- 40.4% of API providers are currently utilizing a tool for testing API security.



With the explosive growth of RESTful APIs, the security layer is often the one that is most overlooked in the architectural design of the API.




Below, one will find some recommendations to consider prior to developing a RESTful API.

### *DATA PROTECTION*

A RESTful API is the way in which a given service can present value to the world. As a result, protection of the data provided via RESTful endpoints should always be a high priority.

You have to define clear access rights, especially for methods like DELETE (deletes a resource) and PUT (updates a resource). Those methods must be accessed by authenticated users only, and for each such call, an audit must be saved.

### *TLS*

Transport Layer Security (TLS) and its predecessor, Secure Sockets Layer (SSL), are cryptographic protocols that provide communications security over a computer network.

When secured by TLS, connections between a client and a server have one or more of the following properties:

- The connection is private (or secure) because symmetric cryptography is used to encrypt the data transmitted.
- The keys for this symmetric encryption are generated uniquely for each connection and are based on a shared secret negotiated at the start of the session.
- The identity of the communicating parties can be authenticated using public-key cryptography.
- The connection ensures integrity because each message transmitted includes a message integrity check using a message authentication code to prevent undetected loss or alteration of the data during transmission.

### *DOS ATTACKS*

In a Denial of Service (DOS) attack, the attacker usually sends excessive messages asking the network or server to authenticate requests that have invalid return addresses. DOS attacks can render a RESTful API into a non-functional state if the right security measures are not taken.

Today, even if your API is not exposed to the public, it still might be accessible by others. This means that REST API security is getting more and more valuable and important. Consider that someone succeeds in making a DOS attack- it means that all the connected clients (partners, apps, mobile devices, and more) will not be able to access your API.

### *ANTI-FARMING*

Today, there are several marketing-heavy websites that offer consumers the best deal on everything from flights to vehicles and even groceries. In many of these cases, the aggregated service is taking advantage of other APIs to obtain the information they want you to utilize. When this happens, the RESTful API is being farmed out for the benefit of another entity.

In case your API does not have an Authorization/Authentication mechanism, it might lead to misuse of your API, loading the servers and the API itself, making it less responsive to others.

## REST API AUTHENTICATION TYPES OVERVIEW

RESTful applications rely on the underlying security of the API ecosystem rather than including security within the REST architecture style. In addition to securing RESTful API calls with the HTTPS protocol, session-based authentication should be utilized. Currently, most RESTful applications leverage OAuth 2.0 and JWT is the newcomer that is gaining more and more popularity with API developers.

OAuth, JWT, and Basic Auth all use headers for transmitting credentials, and API providers should be doing the same with all API keys. While easy to do as parameters, they are more secure as headers.

### BASIC AUTHENTICATION

HTTP Basic authentication implementation is the simplest technique for enforcing access controls to web resources because it doesn't require cookies, session identifiers, or login pages; rather, HTTP Basic authentication uses standard fields in the HTTP header, removing the need for handshakes.

To receive authorization, the client sends the userid and password, separated by a single colon (":") character, within a Base64 encoded string in the credentials.

If the user agent wishes to send the userid "Aladdin" and password "open sesame," it would use the following header field:

```
Authorization: Basic QWxhZGRpbjpvcGVuIHNlc2FtZQ==
```

The Basic authentication scheme is not a secure method of user authentication, nor does it in any way protect the entity, which is transmitted in cleartext across the physical network used as the carrier.

The most serious flaw in Basic authentication is that it results in the essentially cleartext transmission of the user's password over the physical network.

Because Basic authentication involves the cleartext transmission of passwords, it should be used over TLS or SSL protocols (HTTPS) in order to protect sensitive or valuable information.

### API KEYS

Not any formal standard, but something in common practice by API providers, and supported by API management providers. It is the usage of one or two keys that accompany every API call. API keys are really more about identifying the application and user over being  about security, but is perceived as secure by many.

Public REST services without access control run the risk of being farmed, leading to excessive bills for bandwidth or compute cycles. API keys can be used to mitigate this risk. They are also often used by organization to monetize APIs; instead of blocking high-frequency calls, clients are given access in accordance to a purchased access plan.

Typically, an API key gives full access to every operation an API can perform, including writing new data or deleting existing data. If you use the same API key in multiple apps, a broken app could destroy your users' data without an easy way to stop just that one app. Some apps let users generate new API keys, or even have multiple API keys with the option to revoke one that may have gone into the wrong hands. The ability to change an API key limits the security downsides.

### SECURITY ASSESSMENT MARKUP LANGUAGE (SAML)

Security Assertion Markup Language (SAML) is an XML-based framework for authentication and authorization between two entities: a Service Provider and an Identity Provider.

The Service Provider agrees to trust the Identity Provider to authenticate users. In return, the Identity Provider generates an authentication assertion, which indicates that a user has been authenticated.

SAML is a standard single sign-on (SSO) format. Authentication information is exchanged through digitally signed XML documents. It's a complex single sign-on (SSO) implementation that enables seamless authentication, mostly between businesses and enterprises.

### OAUTH 2

Created in 2006, OAuth 2 is an open standard for authentication protocol that provides authorization workflow over HTTP and authorizes devices, servers, applications, and APIs with access tokens instead of credentials. OAuth gained popularity thanks to Facebook, Google, Microsoft, and Twitter, who allow usage of their accounts to be shared with third-party applications or websites.

OAuth 2.0 can be used to read data of a user from another application without compromising the user's personal and sensitive data, like user credentials. It also supplies the authorization workflow for web, desktop applications, and mobile devices.

The previous versions of this spec, OAuth 1.0 and 1.0a, were much more complicated than OAuth 2.0. The biggest change in the latest version is that it's no longer required to sign each call with a keyed hash. The most common implementations of OAuth use one or both of these tokens instead:

- **access token**: sent like an API key, it allows the application to access a user's data; optionally, access tokens can expire.
- **refresh token**: optionally part of an OAuth flow, refresh tokens retrieve a new access token if they have expired.

Since an access token is like a special type of API key, the most likely place to put it is the authorization header, like so:

```
Authorization: Bearer 1234567890abcdef
```

### JSON WEB TOKEN (JWT)

JSON Web Token (JWT) is an open standard extension of OAuth 2.0 for creating access tokens that assert some number of claims.

Whereas API keys and OAuth tokens are always used to access APIs, JSON Web Tokens (JWT) can be used in many different scenarios. In fact, JWT can store any type of data, which is where it excels in combination with OAuth.

Like OAuth access tokens, JWT tokens should be passed in the Authorization header:

```
Authorization: Bearer eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXV
CJ9. eyJob21lcGFnZSI6Imh0dHBzOi8vemFwaWVyLmNvbSIsInRhZ
2xpbmUiOiJaYXBpZXIgbWFrZXMgeW91IGhhcHBpZXIiLCJmb3JtIjo
iaHR0cHM6Ly96YXBpZXIudHlwZWZvcm0uY29tL3RvL0hkRVk0eiJ
9.E3EtYy2y7BRn4eS0RIyDAAh-KAsa6dVV9 VV91ULbBJCRJw
```

## JSON WEB TOKEN INTRODUCTION

### WHAT ARE JSON WEB TOKENS?

JSON Web Token (JWT), pronounced "jot," is an open standard (RFC 7519) that defines a compact and self-contained way for securely transmitting information between parties as a JSON object. This information can be verified and trusted because it is digitally signed.

JWT features:

- **Compact**: Because of their smaller size, JWTs can be sent through a URL, POST parameter, or inside an HTTP header. Additionally, the smaller size means transmission is fast.
- **Self-contained**: The payload contains all the required information about the user, avoiding the need to query the database more than once.

## WHAT DOES A JWT LOOK LIKE?

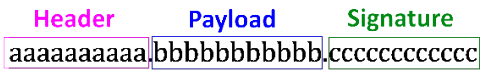
JSON Web Tokens consist of three parts separated by dots (.), which are:

- Header
- Payload
- Signature

For example:

```
aaaaaaaaaa.bbbbbbbbbb.ccccccccccc
```

Since there are three parts separated by a (.), each section is created differently.




## HEADER

The header carries two parts: the type, which is JWT, and the hashing algorithm to use (HMAC SHA256 in this case).

```
{
  “typ”: “JWT”,
  “alg”: “HS256”
}
```

In this JSON, the value of the “`typ`” key specifies that the object is a JWT, and the value of the “`alg`” key specifies which hashing algorithm is being used to create the JWT signature component. In our example, we’re using the HMAC-SHA256 algorithm, a hashing algorithm that uses a secret key, to compute the signature.

Now all that is left is to Base64 Encode this JSON and we have the first part of our JSON web token:

```
eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9
```

## PAYLOAD

The second part of the token is the payload, which contains the claims. Claims are statements about an entity (typically the user) and additional metadata. Notice that the claim names are only three characters long, as JWT is meant to be compact.

There are three types of claims: reserved, public, and private claims.

- **Reserved claims**: These are a set of predefined claims which are not mandatory but recommended, to provide a set of useful, interoperable claims. In the preferred JWT standard, some claims are:

1. `exp`: Expiration Value (Type: Number – DateTime). This is commonly used by the issuer. It has a numeric value that denotes a time interval. The token will expire after this time interval elapses from the current time.
2. `iss`: Issuer (Type: String or URI)
3. `sub`: Subject (Type: String)
4. `aud`: Audience (Type: String or URI)
5. `nbf`: Not Before (Type: Number – DateTime). Denotes a numeric value of time, before which the token must not be accepted for processing.
6. `iat`: Issued At (Type: Number – DateTime). Denotes the numeric format of issued date and time.
7. `jti`: JWT ID (Type: String). The unique identifier for the JWT token.

- **Public claims**: These can be defined at will using JWTs, but to avoid collisions, they should be defined in the IANA JSON Web Token Registry or defined as a URI that contains a collision-resistant namespace.
- **Private claims**: These are the custom claims created to share information between parties that agree on using them. An example of a payload is as follows:

```
{
  “sub”: “AB324901”,
  “name”: “Michael”,
  “admin”: true,
  “exp”: 2601638760
}
```

The Base64 of the above encoded form should look like:

```
eyJzdWIiOiJBQjMyNDkwMSIsIm5hbWUiOiJNaWNoYWVsIiwiYWRtaW
4iOnRydWUsImV4cCI6MjYwMTYzODc2MH0
```

## SIGNATURE

To create the signature part, you have to take the encoded header, the encoded payload, a secret, and the algorithm specified in the header, and sign it.

For example, if you want to use the HMAC SHA256 algorithm, the signature will be created in the following way:

```
data = base64urlEncode( header ) + “.” + base64urlEncode(
payload )
signature = Hash( data, secret );
```

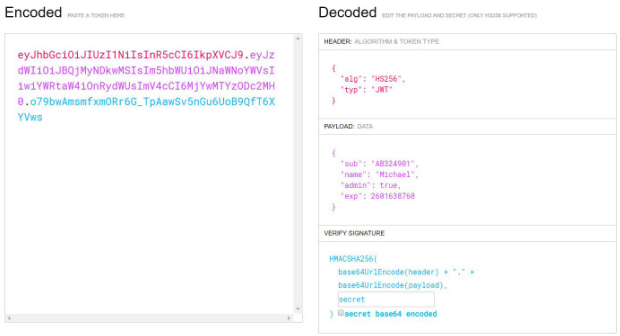
The signature is used to verify that the sender of the JWT is who they say they are, and to ensure that the message wasn't changed along the way.

### PUTTING IT ALL TOGETHER

The output is three Base64 strings separated by dots that can be easily passed in HTML and HTTP environments, while being more compact when compared to XML-based standards such as SAML.

The following shows a JWT that has the previous header and payload encoded, and it is signed with a secret.

```
eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJzdWIiOiJBQjMyNDkwMSIsIm5hbWUiOiJNaWNoYWVsIiwiYWRtaW4iOnRydWUsImV4cCI6MjYzODc2MH0.o79bwAmsmfxmORr6G_TpAawSv5nGu6UoB9QfT6XYVws
```




You can create your own JWT here - **https://jwt.io/**

### WHEN SHOULD YOU USE JSON WEB TOKENS?

Here are some scenarios where JSON Web Tokens are useful:

- **Authentication**: This is the most common scenario for using JWT. Once the user is logged in, each subsequent request will include the JWT, allowing the user to access routes, services, and resources that are permitted with that token. Single sign-on is a feature that widely uses JWT nowadays, because of its small overhead and its ability to be easily used across different domains.
- **Information Exchange**: JSON Web Tokens are a good way of securely transmitting information between parties. Because JWTs can be signed—for example, using public/private key pairs—you can be sure the senders are who they say they are. Additionally, as the signature is calculated using the header and the payload, you can also verify that the content hasn't been tampered with.

### HOW DO JSON WEB TOKENS WORK?

In authentication, when the user successfully logs in using their credentials, a JSON Web Token will be returned and must be saved locally (typically in local storage, but cookies can be also used), instead of the traditional approach of creating a session in the server and returning a cookie.

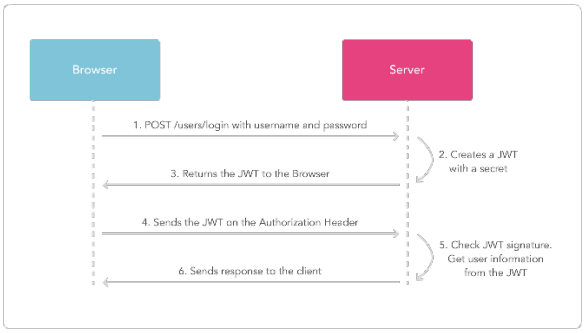
Whenever the user wants to access a protected route or resource, the user agent should send the JWT, typically in the Authorization header using the Bearer schema. The content of the header should look like the following:

```
Authorization: Bearer <token>
```

This is a stateless authentication mechanism as the user state is never saved in the server's memory. The server's protected routes will check for a valid JWT in the Authorization header, and if it's present, the user will be allowed to access protected resources. As JWTs are self-contained, all the necessary information is there, reducing the need to query the database multiple times.

This allows you to fully rely on data APIs that are stateless, and even make requests to downstream services. It doesn't matter which domains are serving your APIs, so Cross-Origin Resource Sharing (CORS) won't be an issue as it doesn't use cookies.

The following diagram shows this process:




### IN CONCLUSION

We went over what JWT is, how the tokens are created and validated, and how they can be used to ensure trust between an application and its users. This is a starting point for understanding the fundamentals of JWTs and why they are useful. JWTs are just one piece of the puzzle in ensuring trust and security in your application.

## SECURE YOUR REST API: BEST PRACTICES

### RATE LIMITING

An API key is a valuable strategy to provide a level of identity to consumers of a RESTful API. In addition to providing tiered services, another benefit of using API keys is the ability to throttle usage of the API, and the logging of all API calls made allows API providers to limit the rate of consumption for all API users. Putting caps on the number of API calls that can be made for any single API resource, dictating consumption by the second, minute, day, other relevant constraint.

### AUTHORIZATION

#### *PROTECT HTTP METHODS*

RESTful APIs often use `GET` (read), `POST` (create), `PUT` (replace/update), and `DELETE` (to delete a record).

Not all of these are valid choices for every single resource collection, user, or action. Make sure the incoming HTTP method is valid for the session token/API key and associated resource collection, action, and record.

### *WHITELIST ALLOWABLE METHODS*

It is common with RESTful services to allow multiple methods for a given URL for different operations on that entity.

For example, a `GET` request might read the entity, while `PUT` would update an existing entity, `POST` would create a new entity, and `DELETE` would delete an existing entity.

It is important for the service to properly restrict the allowable verbs such that only the allowed verbs would work, while all others would return a proper response code (for example, a 403 Forbidden).

### *PROTECT PRIVILEGED ACTIONS AND SENSITIVE RESOURCE COLLECTIONS*

Not every user has a right to every web service. This is vital, as you don't want administrative web services to be misused:

https://example.com/admin/exportAllData

The session token or API key should be sent along as a cookie or body parameter to ensure that privileged collections or actions are properly protected from unauthorized use.

### *PROTECT AGAINST CROSS-SITE REQUEST FORGERY*

For resources exposed by RESTful web services, it's important to make sure any `PUT`, `POST`, and `DELETE` request is protected from Cross-Site Request Forgery. Typically, one would use a token-based approach.

CSRF is easily achieved — even using random tokens — if any XSS exists within your application, so please make sure you understand how to prevent XSS.

## INPUT VALIDATION

Everything you know about input validation applies to RESTful web services, but add 10%, because automated tools can easily fuzz your interfaces for hours on end at high velocity. So:

**Assist the user > Reject input > Sanitize (filtering) > No input validation**

Assisting the user makes the most sense, as the most common scenario is "problem exists between keyboard and chair" (PEBKAC).

### *URL VALIDATIONS*

Web applications/web services use input from HTTP requests (and occasionally files) to determine how to respond.

Attackers can tamper with any part of an HTTP request, including the URL, query string, headers, cookies, form fields, and hidden fields, to try to bypass the site's security mechanisms.

Common names for common input tampering attacks include: forced browsing, command insertion, cross site scripting, buffer overflows, format string attacks, SQL injection, cookie poisoning, and hidden field manipulation.

### *XML INPUT VALIDATION*

XML-based services must ensure that they are protected against common XML-based attacks by using secure XML-parsing.

This typically means protecting against XML External Entity attacks, XML-signature wrapping, etc.

See **http://ws-attacks.org** for examples of such attacks.

## OUTPUT ENCODING

### *SECURITY HEADERS*

To make sure the content of a given resource is interpreted correctly by the browser, the server should always send the Content-Type header with the correct Content-Type, and the Content-Type header should preferably include a charset.

The server should also send an `X-Content-Type-Options: nosniff` to make sure the browser does not try to detect a different Content-Type than what is actually sent (as this can lead to XSS).

Additionally, the client should send an `X-Frame-Options: deny` to protect against drag-and-drop clickjacking attacks in older browsers.

### *JSON ENCODING*

A key concern with JSON encoders is preventing arbitrary JavaScript remote code execution within the browser... or, if you're using Node.js, on the server. It's vital that you use a proper JSON serializer to encode user-supplied data properly to prevent the execution of user-supplied input on the browser.

### *XML ENCODING*

XML should never be built by string concatenation. It should always be constructed using an XML serializer. This ensures that the XML content sent to the browser is parseable and does not contain XML injection. For more information, please see the **Web Service Security Cheat Sheet**.

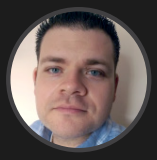
## HTTP STATUS CODES

HTTP defines status codes. When you design your REST API, don't just use 200 for success or 404 for error.

Here are some guidelines to consider for each REST API status return code. Proper error handling may help to validate the incoming requests and better identify the potential security risks.

| Return Code | Message | Description |
|---|---|---|
| 200 | OK | Response to a successful REST API action. The HTTP method can be GET, POST, PUT, PATCH or DELETE. |
| 201 | Created | The request has been fulfilled and the resource created. A URI for the created resource is returned in the Location header. |
| 400 | Bad Request | The request is malformed, such as a message body format error, missing headers, etc. |
| 401 | Unauthorized | Wrong or no authentication ID/ password provided. |
| 403 | Forbidden | Used when the authentication succeeded but the authenticated user doesn't have permission to the requested resource. |
| 404 | Not Found | When a non-existent resource is requested. |
| 406 | Unacceptable | The client presented a content type in the Accept header which is not supported by the server API. |
| 405 | Method Not Allowed | The error for an unexpected HTTP method. For example, the REST API is expecting HTTP GET, but HTTP PUT is used. |
| 413 | Payload Too Large | Used to signal that the request size exceeded the given limit, e.g. regarding file uploads and to ensure that the requests have reasonable sizes. |
| 415 | Unsupported Media Type | The requested content type is not supported by the REST service. This is especially effective when you are working primary with JSON or XML media types. |
| 429 | Too Many Requests | The error is used when there may be a DOS attack detected or the request is rejected due to rate limiting. |





## Written by Guy Levin, CTO, RestCase

Guy Levin (@RestCaseApi) is the CTO of RestCase, a startup company that develops a REST API Development Platform. The platform helps API developers and software companies to speed up development of RESTful services, sharing changes across all team members, minimizing time-to-market and raising the quality and security of the APIs.

Guy is an architect focusing on distributed and cloud systems with over 20 years of experience in software development in a variety of sectors, including medical and healthcare, cybersecurity, and fintech.



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