API7 EE Technical Whitepaper

(Version: 202207)

1. Overall Introduction

API7.ai's API Gateway product (hereinafter referred to as API7) is built based on Apache APISIX, a top-level project of the Apache Software Foundation. API7 consists of 3 components: API Gateway, ManagerAPI and Dashboard Control Panel.

As an important component in microservice architecture, the API gateway is the core entry and exit point for traffic, it is used to process business-related requests, which can effectively solve the problems of massive requests and malicious access to ensure business security and stability.

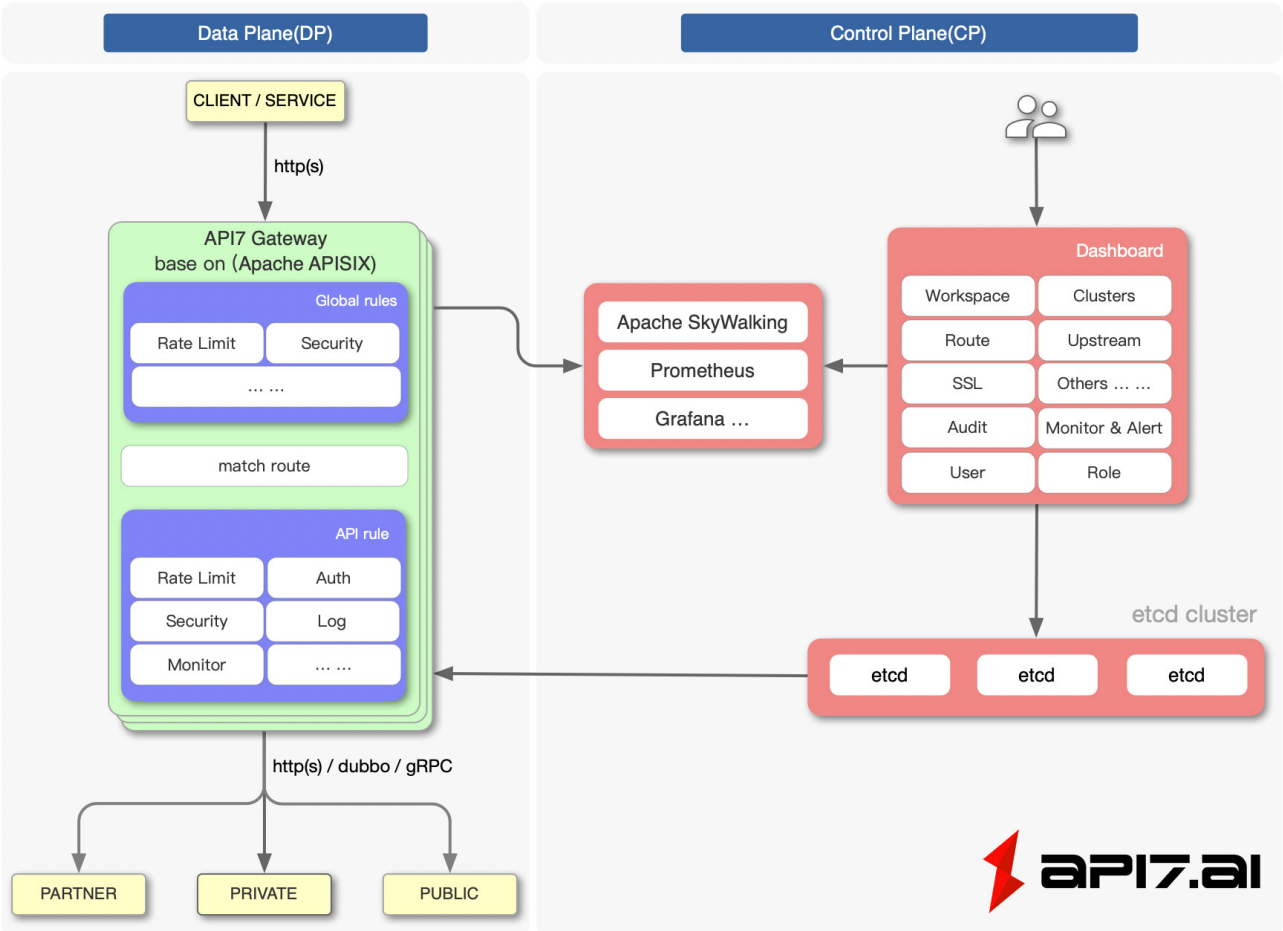


Figure 1-1 API7 Architecture

API7 consists of 3 components: API Gateway, ManagerAPI, and Dashboard Control Panel.

1. **API Gateway**

API Gateway is used to carry and process business traffic. After administrators configure routing rules, the gateway will forward requests to upstream services according to the rules. In addition, with more than 60 built-in plugins, API7 is able to meet most business demands, such as authentication, security protection, traffic control, analysis and monitoring, request/response conversion, etc. If the built-in plugins cannot meet the demands, API7 also support custom plugins written in Lua, Java, Go and Python, which can be used at all stages of request entry and upstream response.

2. **ManagerAPI**

ManagerAPI is used to manage API gateways by accessing their exposed RESTful API interfaces to manage resources such as routes, upstreams, certificates, global plugins, consumers, etc.

3. **Dashboard Control Panel**

Dashboard control panel is a user interface used to simplify API gateway management. It supports monitoring and analysis, log auditing, multi-tenant management, multi-cluster switching, multiple work partitions, and other capabilities. Administrators can operate the API gateway through the Dashboard control panel.

1.1 Architecture

1. **Data Plane**

The data plane is used to receive and process caller requests, using Lua and NGINX to dynamically control request traffic. When a request comes in, it is matched based on predefined routing rules, and the matched request is forwarded by API7 gateway to the corresponding upstream service. During this process, API7 gateway has the ability to use a series of plugins to operate on the request from entry to exit, depending on the configuration of the different plugins in the preset rules. For example, the request may go through several steps such as authentication (to avoid replay attacks, parameter tampering, etc.), request audit (request source information, upstream processing time, etc.), route processing (to obtain the final upstream service address according to the preset rules), request forwarding (the gateway forwards the request to the upstream target node), and request response (after the upstream processing is completed, the gateway returns the result to the caller).

2. **Control Plane**

The control plane contains the ManagerAPI and the default configuration center etcd. when the administrator accesses and operates the console, the console will call the ManagerAPI to send the configuration to the etcd, and with the etcd Watch mechanism, the configuration will take effect in real time in the gateway. For example, an administrator can add a route and configure a rate limit plugin, and when the rate limit threshold is triggered, the gateway will temporarily block access to subsequent requests matching that route. With etcd's Watch mechanism, API7 will notify each gateway node within milliseconds when the administrator updates the configuration in the control panel.

3. **Others**

As shown in Figure 1-1, API7 adopts the architecture of separating the data plane and the control plane, and the configuration center receives and sends down the configuration so that the data plane will not be affected by the control plane. The configuration center is etcd by default, but it also supports Consul, Nacos, Eureka, etc., so you can choose according to your actual situation. In addition, enterprise users only need to focus on the business itself, and most functions not related to the business can be implemented by the built-in plugins of API7, such as authentication, performance analysis, etc.

1.2 Highlights

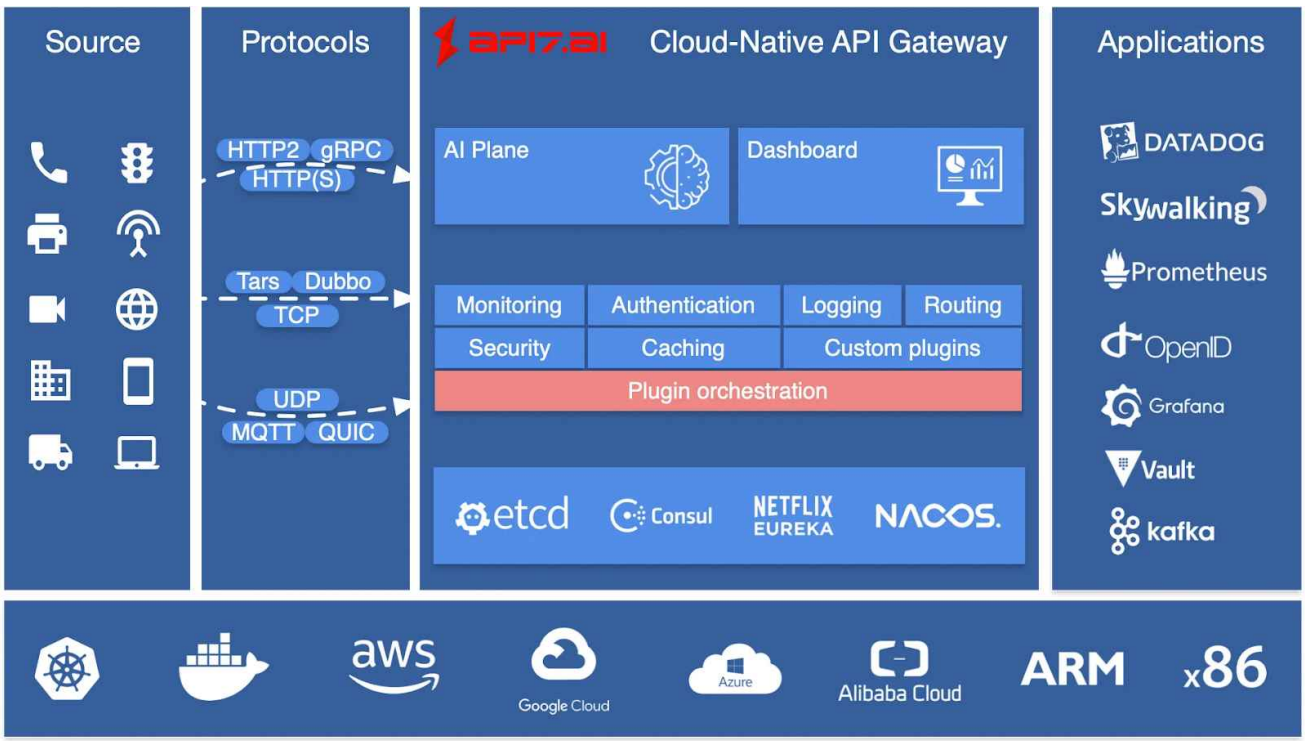


Figure 1-2 API7 Highlights

1. **Cloud Native**

API7 is a cloud-native API gateway. It is neither platform-related nor vendor-locked. API7 supports bare metal, virtual machines, Kubernetes, OpenShift, ARM64, and other platforms. In addition, API7 can easily interface with other components such as SkyWalking, Prometheus, Kafka, Zipkin, etc., to empower the enterprise.

2. **High Availability**

By default, API7 uses etcd as the configuration center. etcd supports distributed and high availability, and has a lot of practical experience in K8s and other fields, which makes API7 easily support millisecond configuration updates and thousands of gateways; the gateways are stateless and can be expanded or reduced at will.

3. **Protocol conversion**

API7 supports many protocol types, such as TCP/UDP, Dubbo, MQTT, gRPC, SOAP, WebSocket, etc.

4. **Security Protection**

API7 has a variety of built-in authentication and security capabilities, such as Basic Auth, JSON Web Token, IP blacklist and whitelist, OAuth, etc.

5. **High Performance**

API7 uses Radixtree algorithm for high-performance, flexible routing with QPS of about 140K and latency of about 0.2 ms in AWS 8-core servers.

6. **Full Dynamic Capability**

API7 supports modifying the gateway configuration, adding or modifying plugins, etc., which can take effect in real time without restarting or reloading the gateway service. API7 also supports dynamic loading of SSL certificates.

7. **High Scalability**

With the flexible plugin mechanism, you can customize the functions for internal services. API7 supports customized load balancing algorithms and routing algorithms. It is not limited to API gateway implementation. You can implement serverless by dynamically executing user-defined functions at runtime, making the gateway edge nodes more flexible.

8. **Rich Governance Capacity**

Such as fault isolation, service meltdown, service downgrade, flow limit and rate limit, etc. After enabling active health check, API7 will support the ability to intelligently track unhealthy upstream nodes and automatically filter unhealthy nodes to improve overall service stability.

1.3 Function Modules

API7 mainly contains the following functional modules:

- **User System:** With the help of user system, the administrator will assign certain accesses and resources for each user in the system, and the user cannot override the accesses to the resources. API7 supports account password login and SSO login.

- **Permission System:** API7 has a built-in Role-Based AccessControl system (RBAC), which allows administrators to create different roles with the help of the console, and by binding users to roles, fine-grained permission control can be achieved.

- **Multi-tenancy (multiple working partitions):** API7 supports multi-tenancy based on working partition isolation, where administrators can create different working partitions and specify which users have access to which resources on the working partition.

- **Multi-environment:** API7 supports multiple etcd clusters, with no data sharing among clusters.

- **Authentication:** API7 includes a variety of authentication plugins, such as basic-auth, jwt-auth, key-auth, wolf-rbac, and so on. In addition, with the built-in HMAC plugin, request parameters can be signed and verified using AK/SK to achieve tamper-proof requests and replay-proof requests, and to achieve the purpose of authentication.

- **Service Routing:** API7 is based on Radixtree for efficient route matching, and is currently the fastest API gateway for matching routes. It supports full path matching, prefix matching, and also supports using NGINX built-in variables as matching conditions to achieve fine-grained routing. In addition, API7 supports traffic mirroring and advanced route matching for fine-grained route management features such as grayscale publishing. It also supports service discovery and multiple registries, and has the ability to triage requests based on parameters such as Header, Query, and Cookie.

- **Protocol Conversion:** API7 supports many communication protocols, such as TCP/UDP, Dubbo, MQTT, gRPC, WebSocket, etc. API7 is able to convert HTTP protocol to other protocols of back-end services. API7 exposes a unified HTTP portal to the outside world, and administrators can complete the protocol conversion settings through the console interface, and support the parameter mapping of requests and back-end services. APIs can be configured through the console interface.

- **Service Governance:** API7 supports service meltdown, flow limiting, rate limiting, IP blacklist and white list, fault isolation, etc., which can be easily and clearly set through the dashboard control panel.

- **Custom plugins:** API7 has more than 60 built-in plugins, covering various categories such as security protection, traffic control, logging, etc., which can meet the needs of most enterprises. For specific business, API7 now supports custom plugins written in Lua, and the plugins can be applied to all stages of traffic in and out. Thanks to the fully dynamic capability, new and modified plugins can take effect in real time without downtime and restart, avoiding interruption of business.

- **Analysis and Monitoring:** API7 has built-in analysis and monitoring functions such as request auditing, monitoring and alerting, statistical reports, etc. API7 can record information of each request of all nodes and conduct statistics of successful requests and abnormal requests. You can view the number of successful requests, failed requests, error codes, request delays and other metrics in the console. In addition, with the ability of Grafana, API7 can meet the demand for more multi-dimensional analysis and monitoring.

- **API Management:** API7 supports API version management, API grouping, API release, API abolishment, online debugging and other functions, and is compatible with OpenAPI 3.0 standard, enabling API document generation, API import/export and other features to execute users' data migration operations.

1.4 Feature List

Categories	Feature Modules	Features	API7	Kong	Zuul2	NGINX
		HTTP/1.1 and HTTP 2	✔️	✔️	✔️	✔️

API and Service Governance	**Protocols**	HTTP/3	✅	✅	❌	❌
		TLS / HTTPS	✅	✅	✅	✅
		MQTT	✅	❌	❌	❌
		TCP	✅	✅	❌	✅
		UDP	✅	✅	❌	✅
		HTTP to gRPC/Dubbo conversion	✅	✅	❌	❌
		Websocket	✅	✅	✅	✅
		Dubbo	✅	❌	❌	❌
		Customized Layer 4 and Layer 7 protocols	✅	❌	❌	❌
	Platforms	Bare Metal	✅	✅	✅	✅
		Virtual Machines	✅	✅	✅	✅
		Kubernetes	✅	✅	✅	✅
		ARM64	✅	✅	✅	✅
		Kunpeng (certified by Huawei Cloud)	✅	❌	❌	❌
		AWS, GCP, Ali Cloud, Tencent Cloud and other public clouds	✅	✅	✅	✅
	Fine-grained Routing	URI Parameter Matching	✅	✅	✅	✅
		HTTP Header Matching	✅	✅	❌	✅
		HTTP Request Method Matching	✅	✅	❌	✅
		Support for all NGINX variables matching	✅	❌	❌	✅
		Support for Lua snippets to implement custom matches	✅	❌	❌	❌
		Support for conditional expressions	✅	❌	❌	❌
		Support IPv6	✅	✅	✅	✅

	GeoIP Geological Location Matching	✅	✅	❌	❌
	Routing Time To Live (TTL)	✅	❌	❌	❌
	Priority Matching	✅	✅	✅	❌
Load-Balance	Round Robin	✅	✅	✅	✅
	Weighted Round Robin	✅	✅	✅	✅
	Consistent Hash (Chash)	✅	✅	❌	✅
	Sticky Session	✅	✅	❌	❌
	Least Connections	✅	✅	❌	✅
	EWMA	✅	❌	❌	❌
	Support for custom load balancing algorithms	✅	❌	✅	❌
Rewrite Request	URI Rewrite	✅	✅	✅	✅
	Add, modify and delete HTTP request headers	✅	✅	✅	✅
	Support 301 and 302 Redirection	✅	✅	✅	✅
	Force a jump to HTTPS	✅	✅	❌	✅
Rewrite Response	Add, modify and delete HTTP response headers	✅	✅	✅	✅
	Modify HTTP response code	✅	✅	✅	✅
	Modify response body	✅	✅	✅	✅
Service Discovery and Registration	Default etcd and support for etcd clustering	✅	❌	❌	❌
	Consul	✅	❌	❌	❌
	Eureka	✅	❌	✅	❌
	Nacos	✅	❌	❌	❌
	Redis	✅	❌	❌	❌
	Traffic Control/ Cluster Traffic	✅	✅	❌	❌

	Fault tolerance and downgrading	Control				
		Rate Limit	✅	✅	❌	✅
		Concurrency Limit	✅	✅	✅	✅
		Upstream Active Health Check	✅	✅	❌	❌
		Upstream Passive Health Check	✅	✅	❌	✅
		Service Meltdown	✅	✅	✅	✅
		Service Downgrade	✅	✅	✅	❌
		API Meltdown	✅	✅	❌	❌
		Timeout	✅	✅	✅	✅
	Traffic Control	Canary Release	✅	✅	❌	✅
		Blue-Green Release	✅	✅	❌	✅
		Traffic Mirroring	✅	❌	❌	✅
		Fault Injection	✅	❌	❌	❌
	API Management	Multi API Aggregation	✅	❌	❌	❌
		Version Management	✅	❌	❌	❌
		Release and Abolish API	✅	❌	❌	❌
		Swagger and OpenAPI	✅	❌	❌	❌
		Generate SDK and documentation	✅	❌	❌	❌
	Plugins Management	Dynamically add, modify and delete plugins	✅	❌	✅	❌
		Plugin orchestration (low code)	✅	❌	❌	❌
		Support for writing custom plugins in Lua, Java and Go	✅	✅	❌	❌
	User Managem	RBAC	✅	❌	❌	❌
		Multi-tenant	✅	❌	❌	❌
		Multi-working partition	✅	✅	❌	❌
		SSL Certificate Management	✅	✅	❌	❌

Security	ent	Control access with Admin API Key and IP restrictions	✅	❌	❌	❌
	Communication Encryption	mTLS	✅	✅	✅	✅
		Automatic rotation of SSL certificates	✅	✅	❌	❌
		Supports GmSSL	✅	❌	❌	❌
	Attack Prevention	IP Blacklist and Whitelist	✅	✅	❌	✅
		URI Blacklist and Whitelist	✅	✅	❌	❌
		Anti-ReDOS attacks	✅	❌	❌	❌
		Anti-Replay Attack	✅	❌	❌	❌
	Authentication	key-auth	✅	✅	❌	❌
		basic-auth	✅	✅	❌	✅
		JWT	✅	✅	❌	❌
		API Signature Verification (HMAC)	✅	✅	❌	❌
		OAuth2	✅	✅	❌	❌
		SSO	✅	✅	❌	❌
		Auth0, Okta, etc.	✅	✅	❌	❌
Observability	Metrics	Prometheus	✅	✅	❌	❌
	Tracing	SkyWalking	✅	❌	✅	❌
		Zipkin	✅	✅	✅	❌
		OpenTracing	✅	✅	✅	❌
	Logs	Kakfa	✅	✅	❌	❌
		HTTP Logger	✅	❌	❌	✅
		TCP Logger	✅	❌	❌	✅
		UDP Logger	✅	❌	❌	❌
	QPS	Single Core Performance	Extreme	High	Low	Extremel

			ly High			y High
	Latency	Minimum latency per request	Excellent	Moderate	Low	Excellent
Cluster and High Availability	**Deployment**	Data plane stateless	✅	✅	✅	❌
		Supports Cluster as Configuration Center	✅	❌	❌	❌
	Cluster Management	Supports configuration and management of multiple clusters	✅	❌	❌	❌
		Supports isolation of permissions between different clusters	✅	❌	❌	❌
	Multi-Layer Network	Global deployment, cross-gateway cluster collaboration	✅	❌	❌	❌
		Automatic selection of optimal paths under topological networks	✅	❌	❌	❌
		Customized plugins under multiplayer networks	✅	❌	❌	❌
		Separate deployment with native open source version support	✅	❌	❌	❌
	Dynamic and hot updates	All changes are hot updated and take effect in real time	✅	❌	❌	✅
		Plugin hot updates	✅	❌	✅	❌
		Hot update of the program itself	✅	✅	❌	✅
	CLI	Command Line Tools	✅	✅	❌	✅
	Admin API	Use REST API for control and easy integration	✅	✅	❌	❌
	Single Node	Use yaml file to define all rules	✅	✅	✅	❌
	Rollback	Supports unlimited rollback of operations	✅	❌	❌	❌

Operations and Maintenance	**Helm charts**	Easier O&M under k8s	✅	❌	❌	✅
	Global Plugins	Simplify operations	✅	✅	✅	❌
	Health Check	Versioning and operational monitoring of data plane nodes	✅	✅	✅	❌
		Provides configuration center status and version information	✅	✅	❌	❌
		Node load status monitoring	✅	✅	❌	❌
	Service Observability	Service Invocation Topology	✅	✅	❌	❌
		Data Throughput	✅	✅	✅	❌
		Response time statistics	✅	✅	✅	❌
		Upstream response time statistics	✅	✅	✅	❌
		Status Code Statistics	✅	✅	✅	❌
		API call statistics	✅	✅	❌	❌

Chart 1-1 API7 Features

1.5 Feature Highlights

1. **API Management**

It covers API design, creation, testing, deployment, management, operation and maintenance, and offline phases, which can further help enterprises optimize API management process and increase enterprise value. With OpenAPI 3.0 standard, you can easily import and export APIs and generate documents to make more use of API capabilities.

2. **Multi-tenant Capability (multiple workspaces)**

API7 supports project isolation through work partitions to support multi-tenant capability. Combined with user system and permission management, different users have different permissions for resources under different work partitions, allowing for fine-grained permission control of resources.

3. **Multi-Protocol Conversion**

Since API7 supports communication protocols such as Dubbo, gRPC, and MQTT, API7 supports unified exposure of RESTful APIs to the outside world, reducing internal service protocol transformation.

4. **Full Dynamic Capability**

With the fully dynamic capability of API gateway, from gateway configuration to plugin modification, it can take effect in real time without restarting the service, avoiding service interruptions that affect business traffic and produce unpredictable results. In addition, API7 also supports dynamic loading of SSL certificates.

5. **Custom Plugins**

API7 has more than 60 plugins built in, which can be used in combination to meet most gateway requirements.

With the unique low-code capability of the API7, you can combine plugins by drawing flowcharts to achieve a more advanced way of using plugins. If existing plugins do not meet your specific needs, customized plugins written in Lua is also supported by API7. Customized plugins can be used at all stages from request entry to response return, such as init, rewrite, access, balancer, header filter, body filter, log, etc.

6. **Analysis and Monitoring**

API7 integrates with Prometheus to obtain detailed API call data, including but not limited to access sources, success rates, top-95 values, top-99 values, success/failure response code distributions, QPS, and other metrics.

7. **Dashboard**

API7 has built-in dashboard control panel and ManagerAPI. Dashboard control panel facilitates users to configure rules through visual panel. ManagerAPI facilitates users to use automation tools or integrate into internal business to control gateway nodes.

8. **Plugin template**

Plugin template is one or a group of commonly used plugin configuration sets, which can be selectively applied to the target API to avoid repeated configuration when creating an API.

9. **Alarm Monitoring**

In the traffic monitoring module, we support the establishment of alarm rules and provide alarm reminders when the alarm rules are hit.

10. **Global Node, visit nearby**

Support nearby access within global gateway nodes. It can provide multi-layer network capabilities. API Gateway forms a local area network through the enterprise backbone network around the world, and has the ability to locate and forward each other.

11. **Data Sovereignty Isolation**

The user's region is located through a multi-layer network, and data sovereignty isolation is achieved by storing the data configured by users with different data sovereignty in different etcd.

2 . Feature Introduction

2.1 Plugins

API7 has more than 60 built-in common plugins, covering authentication, security protection, traffic control, analysis and monitoring, request/response conversion and many other categories. Some popular plugins are listed in the chart below.

Categories	Plugin Name	Function	Scenario
Authentication	Authentication plugin can effectively protect Route, Service from illegal, unprivileged access.		
	authz-keycloak	When the plugin is enabled, API7 will support working with KeyCloak authentication service to complete identity authentication.	Identity Verification
	basic-auth	When the plugin is enabled, the client needs to use the correct account and password when accessing.	
	hmac-auth	When the plugin is enabled, in addition to verifying the validity of the client's identity, its end request parameters will also be signed and verified to avoid parameter tampering or secondary access (replay attack).	

	jwt-auth	When the plugin is enabled, JSON Web Token will be used for validity verification, and the client needs to add the correct Token content to the HTTP request header when accessing.	
	key-auth	When the plugin is enabled, the client needs to carry the correct key in the request header or query string when accessing the resource.	
	wolf-rbac	With this plugin enabled, the gateway will support wolf-based authentication and authorization features.	
	openid-connect	When the plugin is enabled, the gateway will support authentication and token introspection.	
	authz-casbin	When the plugin is enabled, support the authorization scenario based on various access control models.	
	ldap-auth	The built-in authentication plugin can be integrated with the LDAP service and cooperate with the Consumer to realize the authentication function.	
	opa	This plugin is used to integrate with Open Policy Agent. Using this plugin, users can decouple authentication and authorization functions, reducing the complexity of the application system.	
	forward-auth	The plugin uses classic external authentication. When the certification fails, you can implement custom errors or redirect to the certification page.	
Safety	**api-breaker**	After enabling this plugin, the gateway will determine whether the upstream is abnormal according to the configuration, and if it is abnormal, it will directly return the preset error code and no longer access the upstream for a certain period of time.	Meltdown
	consumer-restriction	When this plugin is enabled, if whitelist is set, consumers outside the whitelist will be denied requests by the gateway; if blacklist is set, consumers inside the blacklist will be denied requests by the gateway.	
	cors	Support browser requests to the service by enabling the CORS plugin.	
	fault-injection	When the fault injection plugin is enabled, it will return the specified HTTP status code and response content	Fault Injection

		directly to the incoming request for service maintenance purposes.	
	ip-restriction	Restrict access to services by whitelisting or blacklisting IP addresses, setting single or multiple addresses, or setting IP ranges in a CIDR fashion.	
	referer-restriction	When the plugin is enabled, the Referer information in the request header is used to determine if the request needs to be restricted.	
	request-validation	When the gateway forwards the request upstream, the plugin uses JSONSchema to validate the request header against the request body, and requests that fail the validation are rejected.	
	uri-blocker	When the plugin is enabled, the gateway will return the specified status code when the request path matches the preset rule.	
	ua-restriction	When this plugin is enabled, access to services or interfaces can be restricted by whitelisting or blacklisting specified User-Agent.	
Traffic Control	**limit-conn**	Enabling this plugin will limit the number of concurrent requests.	Flow and Rate limit
	limit-count	With this plugin enabled, requests that exceed a preset value within a fixed time window will be rejected.	
	limit-req	When enabled, the plugin will use the Leaky Bucket algorithm to limit the request rate.	
	traffic-split	The plugin allows us to dynamically control the ratio of traffic directed to different upstream services.	Grayscale
	proxy-control	When this plugin is enabled, the behavior of the NGINX proxy can be dynamically controlled.	
	client-control	After enabling this plugin, it can dynamically control the behavior of NGINX processing client requests.	
Serverless	The Serverless plugin dynamically executes Lua code in the gateway access phase to enable the execution of FaaS functions in a serviceless environment.		
	serverless-post-function	The functions configured in this plugin will be run before other plugins.	

	serverless-pre-function	The functions configured in this plugin will be run after other plugins.	
	azure-functions	The plugin is a built-in serverless plugin for seamless integration with Azure Serverless Function (as a dynamic upstream) to proxy all requests for a specific URI to the Microsoft Azure Cloud.	
	openwhisk	This plugin is for integration with the Apache Open Whisk serverless platform and can be set on the route in place of Upstream which will take over the request and send it to the Open Whisk API endpoint.	
	aws-lambda	A built-in serverless plugin for seamless integration with AWS Lambda (as a dynamic upstream), proxying all requests for a specific URI to AWS Lambda.	
Observability	**error-log-logger**	The plugin will push the contents of the error.log file generated by the gateway to the specified server using TCP protocol.	
	http-logger	This plugin is used to send request data, response data, and contextual information to the HTTP server.	
	kafka-logger	The plugin will send the log data to Kafka.	
	prometheus	The plugin will expose the relevant metrics of the gateway in Prometheus' data format.	
	request-id	The plugin will add a request-id request header to each request processed by the gateway to identify the API request.	
	skywalking	SkyWalking is an observability analysis platform, and this plugin will proactively report data to SkyWalking so that we can easily view the status of the gateway through SkyWalking.	
	sls-logger	This plugin is used to send request data, response data and contextual information to AliCloud SLS logging service.	
	syslog	This plugin is used to send request data, response data, and contextual information to Syslog.	
	tcp-logger	This plugin is used to send access-log data as TCP to the specified server	
		This plugin is used to send access-log data to the	

	udp-logger	specified server as UDP. Since UDP does not require three handshakes, it is efficient and has good real-time transmission.	
	zipkin	The plugin will report gateway timing and trace data to Zipkin, including but not limited to TraceID, node information, request information, latency, etc. This can help us locate problems encountered with the gateway through Zipkin.	
	node-status	A request status query plugin of APISIX, which returns basic status information.	
	datadog	A built-in monitoring plugin that integrates seamlessly with Datadog to push its custom metrics to the DogStatsD server via the UDP protocol.	
	skywalking-logger	Enable this plugin to push Access Log data to the Sky Walking OAP server via HTTP. If there is a tracing context in the context, the plugin will automatically associate the trace with the log.	
	rocketmq-logger	After enabling this plugin, API request logs can be pushed to external RocketMQ clusters in the form of JSON.	
	log-rotate	After this plugin is enabled, the regular segmentation of the access and error logs in the logs directory can be done automatically. Through the configuration parameters, you can set how often the logs are split at each interval, and how many logs are kept recently (after the specified number is exceeded, the old files are automatically deleted).	
	google-cloud-logging	The plugin provides the function of pushing the requested log data to the Google Cloud log service in the form of a batch queue.	
	splunk-hec-logging	This plugin is used to forward request logs to Splunk HTTP Event Collector (HEC) for storage and analysis.	
	batch-requests	The plugin will support the use of Pipeline form to receive multiple requests and send them to the corresponding upstream service, whose response content is a combination of the response content of multiple requests. This is useful when a client wants to access multiple APIs.	

Others	**grpc-transcode**	The plugin will support sending RESTful API requests to the gRPC upstream service.	
	proxy-cache	The plugin will support caching upstream service response content, when the content requested by the client already exists in the cache, the content will be returned directly from the cache, without the need to request the upstream service again. This will effectively reduce the pressure on the upstream service. In addition, when the upstream node fails, it can also temporarily return the cached content without returning the error page to improve the user experience.	
	proxy-mirror	The plugin supports mirrored replication of requests for better bypassed request analysis.	
	proxy-rewrite	Before the request sent by the client reaches the upstream service, the plugin will modify the request according to the specified rules, including but not limited to the request body, request header, request path and other parameters.	
	response-rewrite	Before the response from the upstream service reaches the client, the plugin will modify the response content according to the specified rules, including but not limited to the response body, response header and other parameters.	
	redirect	This plugin can implement URI redirection.	
	gzip	This plugin can dynamically set the compression behavior of NGINX.	
	real-ip	This plugin is used to dynamically change the IP and Port of the real client passed to the Gateway.	
	server-info	This plugin can periodically report basic service information to etcd plugins.	
	ext-plugin-pre-req	Run a specific External Plugin inside the Plugin Runner before executing most of the built-in Lua plugins.	
	ext-plugin-post-req	This plugin is similar to the ext-plugin-pre-req plugin, the only difference: it works after the built-in Lua plugin executes and before the request reaches the upstream.	
	grpc-web	A proxy plugin that translates requests from gRPC web clients to gRPC Server.	

	dubbo-proxy	When enabled, the plugin allows proxying HTTP requests to Apache Dubbo.	
	mqtt-proxy	After this plugin is enabled, the MQTT service can be brokered, and dynamic load balancing can be achieved according to the MQTT client_id.	

Chart 2-1 API7 plugins

2.2 Authentication

API7 has built-in authentication authentication plugins such as key-auth, basic-auth, jwt-auth, etc. Taking HMAC plugin as an example, API7 can work with AK/SK to encrypt the request parameters to ensure that the request has not been tampered with.

Request parameters such as Request Path, Request Query String, timestamp, and signature algorithm, are included in Request Header to avoid request tampering and replay attacks.

2.3 Canary Release

Routing is the core function of the API gateway, which is used to route and match requests passing through the API gateway and forward them to the corresponding upstream service. When the upstream service finishes processing, the result is returned to the client. If a request does not match a route, the gateway will return a 404 status code because the route has not been published to the gateway or the route is not configured.

With API7's powerful routing capabilities, the need for grayscale publishing and blue-green deployment can also be realized so that enterprises can smoothly upgrade their services in a stable manner. In addition, when the API gateway forwards requests to upstream services, it will carry some HTTP request headers to mark that the traffic came from the gateway.

Take a Canary Release as an example: after starting a Canary Release, first start the new version of the service (application) and give it to testers to test the new version. If the test is OK, then a small amount of traffic can be switched to the new version, followed by a running status check of the new version and the collection of various data. When the new version is confirmed to be working well, then gradually switch more traffic to the new version. Until 100% of the traffic is switched to the new version, then the old version is shut down and the Canary Release is completed. If you find any problem with the new version during the Canary Release, you can

immediately switch the traffic back to the old version, so that the negative impact will be kept to a minimum.

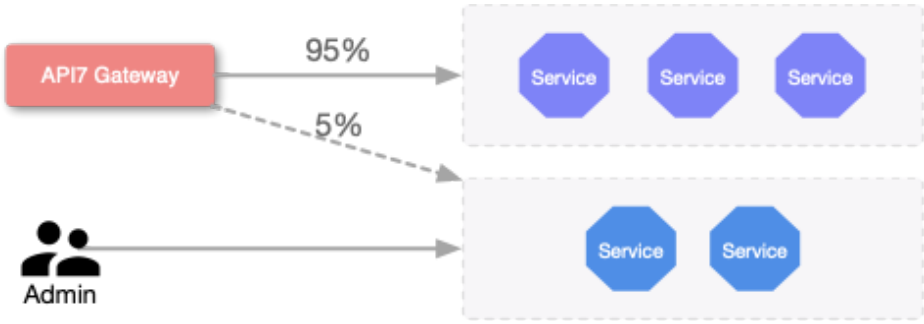


Chart 2-1 Canary Release

2.4 Service Governance

API7 has built-in service governance features such as flow and rate limiting, service meltdown, IP blacklist and whitelist, and fault isolation.

1. Flow Limit and Rate Limit

API7 limits the flow and rate based on the Leaky Bucket algorithm, with three built-in limit-count, limit-req, and limit-conn plugins to limit the flow and rate:

Name	Description
limit-count	rate limit based on fixed window
limit-req	Request rate limit based on the leaky bucket principle
limit-conn	Limit concurrent requests

Chart 2-2 Flow Limit and Rate Limit Plugins

Take limit-req for example, which contains the following parameters:

Parameter	Type	Required	Range	Description
rate	integer	Yes	> 0	The maximum allowed request rate. Requests greater than rate but less than rate + burst will be delayed. The unit is seconds.

burst	integer	Yes	>= 0	The rate of requests that are allowed to be delayed.
key	string	Yes	remote_addr, server_addr,http_x_real_ip, http_x_forwarded_for,consumer_name	The keyword used to limit the request rate (request count basis).
rejected_code	integer	Yes	200 ~ 599	This status code will be returned when the request rate exceeds rate + burst. The default status code is 503.

Chart 2-3 limit-req plugin Parameters

After creating the route through the control panel, bind the limit-req plugin for it, assuming that the rate is set to 1, burst to 2, and rejected_code to 503, which means that the rate per second is 1. When the rate exceeds 1 but is less than 3, the request will be delayed; when the rate exceeds 3, the request will be rejected and the rejected_code will be returned, such as 503.

2. **IP blacklist and whitelist**

API7 has a built-in IP blacklist and whitelist plugin that allows administrators to set it through the control panel. By setting up a blacklist IP list or a whitelist IP list, you can control the access to resources of routes and services.

3. **Meltdown**

When a request arrives at the API gateway, there are 3 sorts of possibile outcomes:

- A normal request and a normal response.
- The request is normal and the response is abnormal.
- The request is abnormal.

When a large number of requests arrive, if the upstream service cannot respond to the requests in time and is in a blocking state, there will be a situation where the upstream service is defeated. As an API gateway, it should be able to detect and handle abnormal problems in time to avoid more serious problems. In this case, API gateway service degradation will come into play.

2.5 Log Auditing

API7 has a built-in log auditing module, which collects system security events, administrator operation records, system operation logs, system operation status and other kinds of information in the information system centrally, and then stores and manages them centrally in the form of logs in a unified format after normalization, filtering and consolidation, combining with rich log statistical summary and correlation analysis functions to realize comprehensive auditing of information system logs. Through post-event analysis and reporting system, administrators can easily and efficiently conduct targeted security audits on information systems; when encountering special security events or configuration failures, the log auditing system can help administrators conduct rapid configuration positioning and rollback. Only administrators with authority can perform operation rollback.

2.6 Refined Routing

API7 will triage the matched requests according to the preset weights and parameters.

1. Triage by weight

The administrator creates each upstream object through the control panel, and during the configuration process, allows to set the weight value for each upstream service instance, if the value is 0, it means that no traffic is assigned to the example. In addition, upstream supports algorithms such as round robin polling with weight, chash, and exponentially weighted moving average (EWMA).

2. Streaming by parameters

The API gateway supports triage based on each parameter of the request and its value, for example:

Parameters	Value

Request Header	{
	"vars": [["http_user_agent", "~*", "android"]], // Whether request header User-Agent matches android
	"uri": "/hello",
	"upstream_id": "1"
	}

Request Host	{ "hosts": ["www.my.com"], // Whether host matches "www.my.com" "uri": "/hello",

	"upstream_id": "1" }

Request Path	{
	"uri": "/hello", // Whether path matches "/hello"
	"upstream_id": "1"
	}

Request Query String	{
	"vars": [["arg_theme", "==", "light"]], // Whether theme in query string matches light
	"uri": "/hello",
	"upstream_id": "1"
	}

Request Cookie	{
	"vars": [["cookie_token", "==", "1234"]], // Whether token field in cookie matches "1234"
	"uri": "/hello",
	"upstream_id": "1"
	}

Chart 2-4 Streaming Parameters

When the request is matched with each parameter, the traffic will be assigned to the corresponding upstream service.

2.7 Monitoring and Alerting

API7 records the basic information and status of each request. With the help of the statistical report page in the dashboard control panel, administrators can see the status of each service call, status code distribution, number of successes, number of failures, top 95 values, top 99 values and other information. It is convenient for administrators to understand the health of the system. In addition, the data plane will regularly report the traffic processing situation, and the administrator can view the gateway operation status and other indicators, such as error rate, number of requests, status code distribution, etc., within a certain time period through the control panel. When the administrator presets the alarm rules through the control panel, if the traffic reported by the gateway matches the rules, it will trigger the preset policies, such as sending station letters, email alerts, SMS and Webhook notifications, etc.

2.8 Protocol Conversion

API7 exposes RESTful APIs uniformly to the outside world, which can be set by administrators in the control panel. These APIs correspond to microservices/upstream services in the enterprise and support proxies for protocols such as Dubbo, gRPC, WebServices, MQTT, etc., in addition to common HTTP services.

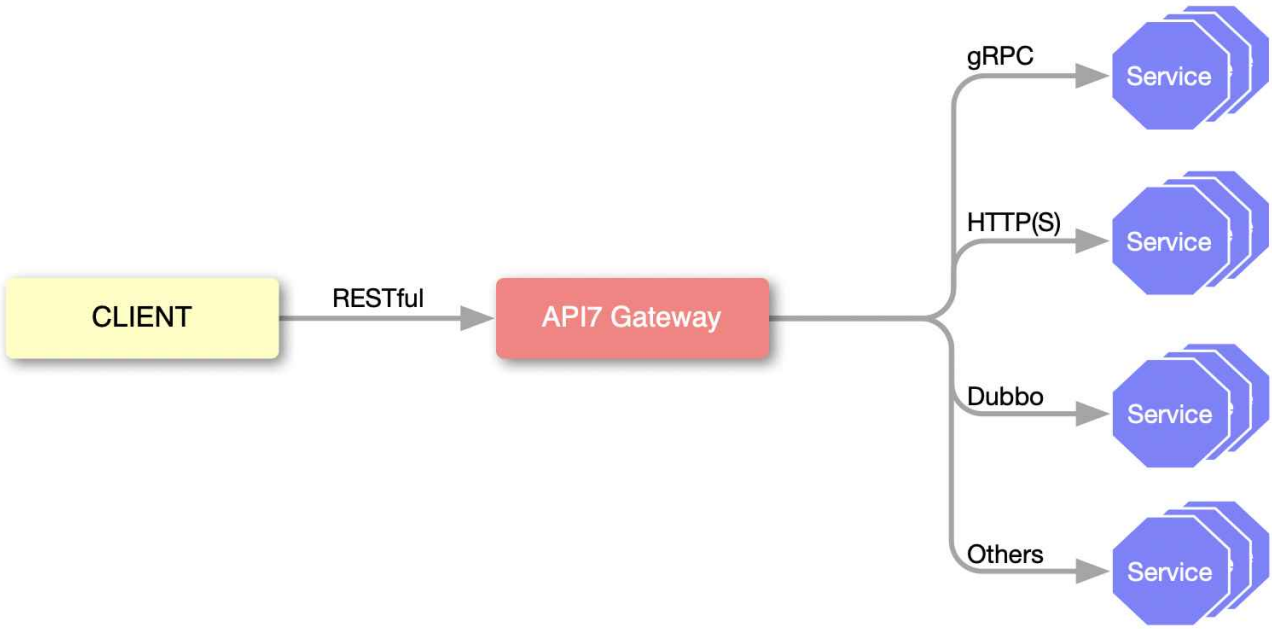


Figure 2-2 Protocol Conversion

The control panel allows administrators to create upstream services of different protocols and supports creating route objects to bind to upstream services, which are the APIs to be used by the caller. in the process of configuring routes, administrators need to set the HTTP methods (such as GET, POST, PATCH, etc.) listened to by the route, HTTP host name, and other parameters to match requests as rules.

After the route is configured and published, when the request is processed by the API gateway, the API gateway will match the corresponding request according to each routing rule, construct the request content of different protocols and forward it to the upstream service.

2.9 Multi-tenant and Multi-working Partition

API7 has a built-in workspace module, super administrators need to create multiple workspaces, then create ordinary users and assign different permissions (in the configuration of permissions, you can bind workspace and resource permissions), so that the combination of the user system and permission management can achieve different users in different workspaces, different

permissions for different resources, in order to achieve fine-grained control of resources permissions.

2.10 Performance

API7 adopts excellent performance solutions in all aspects from route matching, JSONSchema validation, and plugin operation.

Take route matching as an example, API7 uses the self-developed radixtree (open-sourced by API7.ai) algorithm for routing, which does not reduce efficiency when the number of routes is very large because its time complexity is O(K) (K is the length of the route string, independent of the number of routes).

The following figure shows the latency comparison between API7 and Kong Enterprise Edition (Kong EE) at 10000 rps.

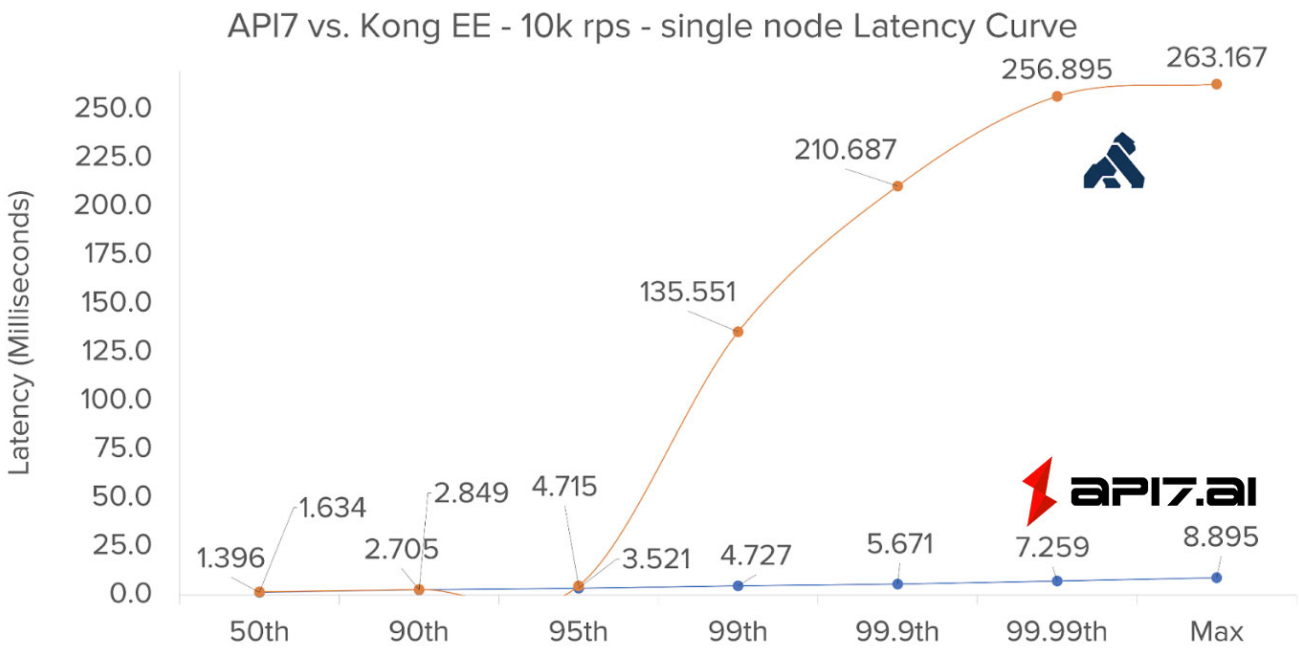
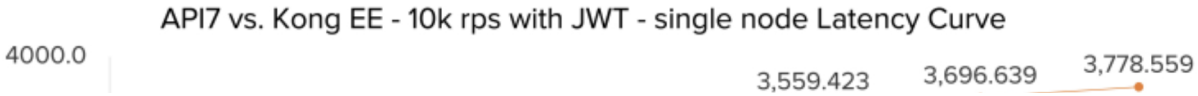


Figure 2-3 API7 v.s. Kong EE with 10krps and single node

As shown in Figure 2-3, the latency performance of API7 is very stable, 99.9% of requests are processed within 6 milliseconds; while Kong EE's latency is 10 times higher than API7.

The following figure shows the latency performance for the same 10,000 rps with the JWT authentication plugin enabled:



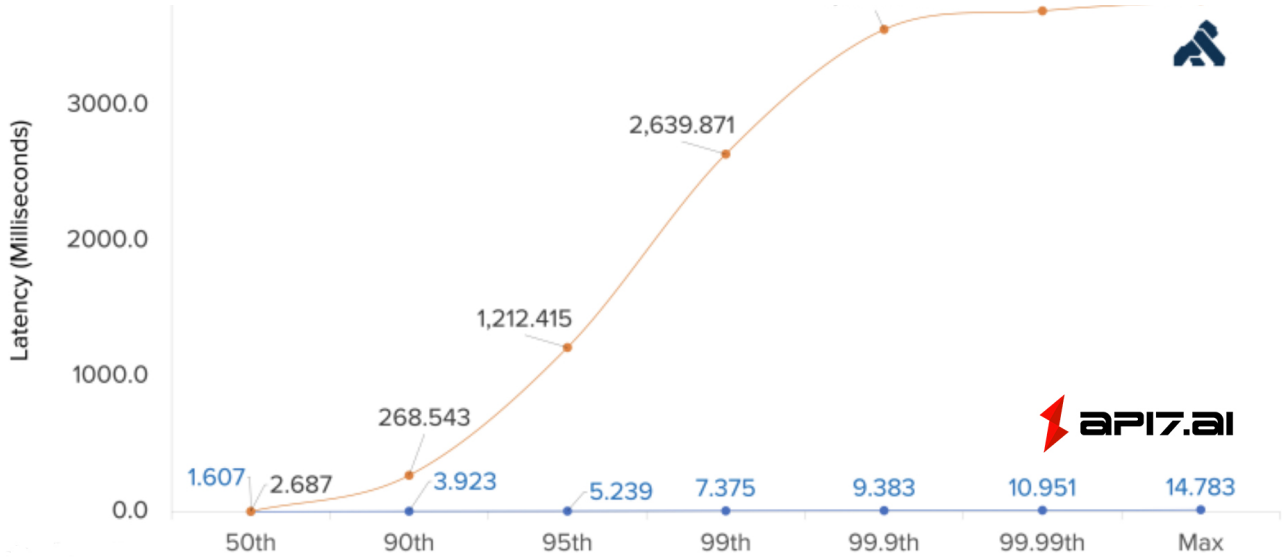


Figure 2-4 API7 v.s. Kong EE with 10krps, JWT Auth and single node

As shown in Figure 2-4, the request latency performance of API7 remains stable with the JWT plugin enabled, while the latency of Kong Enterprise Edition is hundreds of times higher than API7, which is a significant difference.