

Rate Limiter - 1 Hour Session

Duration: 60 minutes **Level:** Intermediate



Session Agenda

- Introduction to Rate Limiting (10 min)
- Rate Limiting Algorithms (15 min)
- Distributed Rate Limiting (15 min)
- Implementation Patterns (10 min)
- Best Practices & Real-World Examples (10 min)

🎯 Learning Objectives

By the end of this session, you will understand:

- What rate limiting is and why it's essential
- Different rate limiting algorithms and their trade-offs
- How to implement distributed rate limiting
- Common patterns and best practices
- How to choose the right algorithm for your use case

1. Introduction to Rate Limiting (10 min)

What is Rate Limiting?

Rate limiting is a technique to control the rate of requests a client can make to a service within a specified time window.

 **Quote** “Rate limiting is the first line of defense against abuse and the last line of defense for availability.”

Why Rate Limit?

Protection & Control: -  **DDoS Protection:** Prevent denial-of-service attacks -  **Cost Control:** Limit expensive API calls -  **Fair Usage:** Ensure equitable resource distribution -  **System Stability:** Prevent cascading failures -  **Predictable Performance:** Maintain SLAs

Rate Limiting Dimensions

Rate Limit Dimensions:

1. By User/API Key
 - └ 1000 requests/hour per user
2. By IP Address
 - └ 100 requests/minute per IP
3. By Endpoint
 - └ /api/search: 10 req/sec
 - └ /api/upload: 5 req/min
4. By Service Tier
 - └ Free: 100 req/day
 - └ Pro: 10,000 req/day
 - └ Enterprise: Unlimited

Key Metrics

METRIC	DESCRIPTION	EXAMPLE
Rate	Requests allowed per time unit	100 req/sec
Burst	Maximum requests in short burst	150 req
Window	Time period for rate calculation	1 minute
Quota	Total requests in longer period	10,000/day

2. Rate Limiting Algorithms (15 min)

1. Token Bucket Algorithm

Concept: Tokens are added to a bucket at a fixed rate. Each request consumes a token.

Token Bucket Visualization:

Bucket Capacity: 10 tokens

Refill Rate: 2 tokens/second

Time 0s: [🟡🟡🟡🟡🟡🟡🟡🟡🟡🟡] 10 tokens

Request: [🟡🟡🟡🟡🟡🟡🟡🟡🟡🟡] 9 tokens (1 consumed)

Time 1s: [🟡🟡🟡🟡🟡🟡🟡🟡🟡🟡] 10 tokens (refilled, capped)

Burst 5: [🟡🟡🟡🟡🟡] 5 tokens (5 consumed)

Time 2s: [🟡🟡🟡🟡🟡] 7 tokens (+2 refilled)

Implementation:

```

import time
from threading import Lock

class TokenBucket:
    def __init__(self, capacity: int, refill_rate: float):
        self.capacity = capacity
        self.tokens = capacity
        self.refill_rate = refill_rate # tokens per second
        self.last_refill = time.time()
        self.lock = Lock()

    def _refill(self):
        now = time.time()
        elapsed = now - self.last_refill
        tokens_to_add = elapsed * self.refill_rate
        self.tokens = min(self.capacity, self.tokens + tokens_to_add)
        self.last_refill = now

    def consume(self, tokens: int = 1) → bool:
        with self.lock:
            self._refill()
            if self.tokens ≥ tokens:
                self.tokens -= tokens
                return True
            return False

# Usage
bucket = TokenBucket(capacity=10, refill_rate=2)

for i in range(15):
    if bucket.consume():
        print(f"Request {i+1}: Allowed")
    else:
        print(f"Request {i+1}: Rate limited")

```

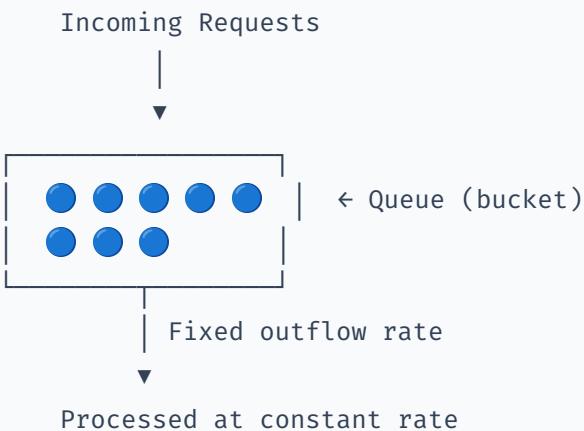
Pros: - ✓ Allows bursts up to bucket capacity - ✓ Smooth rate limiting over time - ✓ Memory efficient ($O(1)$ per client)

Cons: - ✗ Burst can overwhelm downstream services - ✗ Requires careful capacity tuning

2. Leaky Bucket Algorithm

Concept: Requests enter a queue (bucket) and are processed at a fixed rate. Overflow is rejected.

Leaky Bucket Visualization:



Implementation:

```

import time
from collections import deque
from threading import Lock

class LeakyBucket:
    def __init__(self, capacity: int, leak_rate: float):
        self.capacity = capacity
        self.leak_rate = leak_rate # requests per second
        self.queue = deque()
        self.last_leak = time.time()
        self.lock = Lock()

    def _leak(self):
        now = time.time()
        elapsed = now - self.last_leak
        leaks = int(elapsed * self.leak_rate)

        for _ in range(min(leaks, len(self.queue))):
            self.queue.popleft()

        if leaks > 0:
            self.last_leak = now

    def allow(self) -> bool:
        with self.lock:
            self._leak()
            if len(self.queue) < self.capacity:
                self.queue.append(time.time())
            return True
        return False

# Usage
bucket = LeakyBucket(capacity=5, leak_rate=1)

```

Pros: - ✓ Constant output rate (no bursts) - ✓ Predictable downstream load - ✓ Good for APIs with strict rate requirements

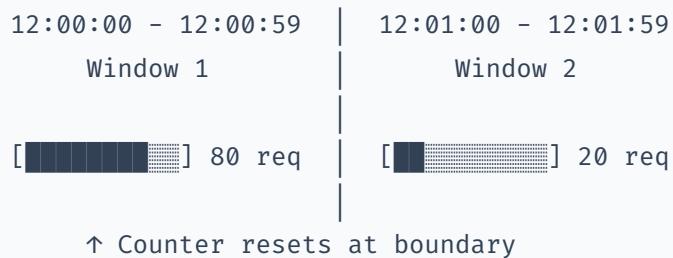
Cons: - ✗ No burst allowance - ✗ Recent requests may wait behind old ones

3. Fixed Window Counter

Concept: Count requests in fixed time windows. Reset counter at window boundary.

Fixed Window Counter:

Window: 1 minute, Limit: 100 requests



Implementation:

```

import time
from threading import Lock

class FixedWindowCounter:
    def __init__(self, limit: int, window_seconds: int):
        self.limit = limit
        self.window_seconds = window_seconds
        self.counters = {} # client_id → (window_start, count)
        self.lock = Lock()

    def _get_window_start(self) → int:
        return int(time.time() // self.window_seconds) * self.window_seconds

    def allow(self, client_id: str) → bool:
        with self.lock:
            window_start = self._get_window_start()

            if client_id not in self.counters:
                self.counters[client_id] = (window_start, 0)

            stored_window, count = self.counters[client_id]

            # New window - reset counter
            if stored_window ≠ window_start:
                self.counters[client_id] = (window_start, 1)
                return True

            # Same window - check limit
            if count < self.limit:
                self.counters[client_id] = (window_start, count + 1)
                return True

        return False

# Usage
limiter = FixedWindowCounter(limit=100, window_seconds=60)

```

Pros: - ✓ Simple to implement - ✓ Memory efficient - ✓ Easy to understand

Cons: - ✗ Boundary burst problem (2x limit at window edges)

Boundary Burst Problem:

12:00:30 - 12:00:59: 100 requests (allowed)

12:01:00 - 12:01:30: 100 requests (allowed)

↓

Result: 200 requests in 1 minute! (2x limit)

4. Sliding Window Log

Concept: Store timestamp of each request. Count requests within sliding window.

Sliding Window Log:

Current time: 12:01:30

Window: 1 minute

Limit: 5 requests

Timestamps: [12:00:45, 12:01:00, 12:01:15, 12:01:20, 12:01:25]



All within last 60 seconds = 5 requests

New request at 12:01:30 → REJECTED (limit reached)

Implementation:

```

import time
from collections import deque
from threading import Lock

class SlidingWindowLog:
    def __init__(self, limit: int, window_seconds: int):
        self.limit = limit
        self.window_seconds = window_seconds
        self.logs = {} # client_id → deque of timestamps
        self.lock = Lock()

    def allow(self, client_id: str) → bool:
        with self.lock:
            now = time.time()
            window_start = now - self.window_seconds

            if client_id not in self.logs:
                self.logs[client_id] = deque()

            # Remove expired timestamps
            while self.logs[client_id] and self.logs[client_id][0] <
            window_start:
                self.logs[client_id].popleft()

            # Check limit
            if len(self.logs[client_id]) < self.limit:
                self.logs[client_id].append(now)
                return True

        return False

# Usage
limiter = SlidingWindowLog(limit=100, window_seconds=60)

```

Pros: - ✓ Accurate rate limiting - ✓ No boundary burst problem - ✓ Smooth rate enforcement

Cons: - ✗ High memory usage (stores all timestamps) - ✗ O(n) cleanup operation

5. Sliding Window Counter

Concept: Hybrid of fixed window and sliding window. Weighted average of current and previous window.

Sliding Window Counter:

Previous Window (12:00-12:01): 84 requests

Current Window (12:01-12:02): 36 requests

Current time: 12:01:15 (25% into current window)

$$\begin{aligned}\text{Weighted count} &= 84 * (1 - 0.25) + 36 * 0.25 \\ &= 84 * 0.75 + 36 * 0.25 \\ &= 63 + 9 \\ &= 72 \text{ requests}\end{aligned}$$

If limit = 100, new request is ALLOWED

Implementation:

```

import time
from threading import Lock

class SlidingWindowCounter:
    def __init__(self, limit: int, window_seconds: int):
        self.limit = limit
        self.window_seconds = window_seconds
        self.windows = {} # client_id → {prev_count, curr_count,
curr_window}
        self.lock = Lock()

    def _get_window_start(self) → int:
        return int(time.time() // self.window_seconds) * self.window_seconds

    def allow(self, client_id: str) → bool:
        with self.lock:
            now = time.time()
            window_start = self._get_window_start()
            window_progress = (now - window_start) / self.window_seconds

            if client_id not in self.windows:
                self.windows[client_id] = {
                    'prev_count': 0,
                    'curr_count': 0,
                    'curr_window': window_start
                }

            w = self.windows[client_id]

            # Check if we moved to a new window
            if w['curr_window'] ≠ window_start:
                if w['curr_window'] == window_start - self.window_seconds:
                    w['prev_count'] = w['curr_count']
                else:
                    w['prev_count'] = 0
                    w['curr_count'] = 0
                    w['curr_window'] = window_start

            # Calculate weighted count
            weighted_count = (w['prev_count'] * (1 - window_progress) +
                               w['curr_count'])

```

```

        if weighted_count < self.limit:
            w['curr_count'] += 1
            return True

    return False

# Usage
limiter = SlidingWindowCounter(limit=100, window_seconds=60)

```

Pros: - ✓ Smooths boundary burst problem - ✓ Memory efficient ($O(1)$ per client) - ✓ Good balance of accuracy and efficiency

Cons: - ✗ Approximation (not 100% accurate) - ✗ Slightly more complex than fixed window

Algorithm Comparison

ALGORITHM	MEMORY	ACCURACY	BURST HANDLING	COMPLEXITY
Token Bucket	$O(1)$	High	Allows bursts	Low
Leaky Bucket	$O(n)$	High	No bursts	Medium
Fixed Window	$O(1)$	Low	Boundary burst	Low
Sliding Log	$O(n)$	Highest	Smooth	Medium
Sliding Counter	$O(1)$	High	Smooth	Medium

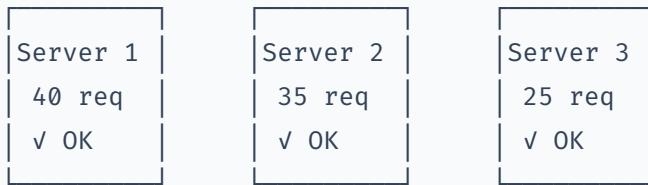
3. Distributed Rate Limiting (15 min)

The Challenge

In distributed systems, rate limiting becomes complex because requests can hit any server.

Problem: User makes 100 requests

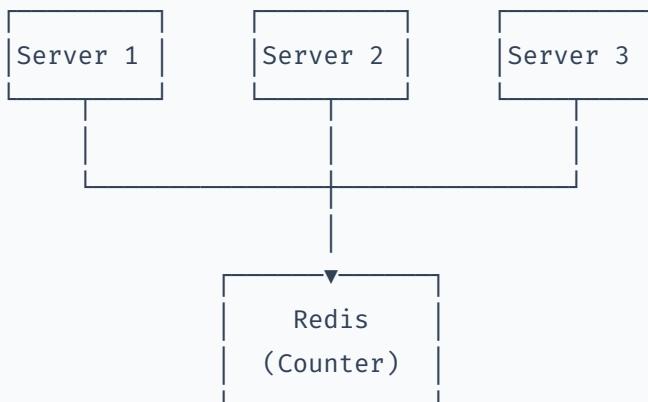
Without coordination:



Total: 100 requests allowed (should be limited to 50!)

Solution 1: Centralized Rate Limiter

Use a shared data store (Redis) for rate limit counters.



Redis Implementation:

```

import redis
import time

class DistributedRateLimiter:
    def __init__(self, redis_client, limit: int, window_seconds: int):
        self.redis = redis_client
        self.limit = limit
        self.window = window_seconds

    def is_allowed(self, client_id: str) → bool:
        key = f"rate_limit:{client_id}"
        current_time = int(time.time())
        window_start = current_time - self.window

        # Use Redis pipeline for atomic operations
        pipe = self.redis.pipeline()

        # Remove old entries
        pipe.zremrangebyscore(key, 0, window_start)

        # Count current entries
        pipe.zcard(key)

        # Add current request
        pipe.zadd(key, {str(current_time): current_time})

        # Set expiry
        pipe.expire(key, self.window)

        results = pipe.execute()
        request_count = results[1]

    return request_count < self.limit

# Usage
r = redis.Redis(host='localhost', port=6379)
limiter = DistributedRateLimiter(r, limit=100, window_seconds=60)

if limiter.is_allowed("user_123"):
    print("Request allowed")

```

```
else:  
    print("Rate limited")
```

Lua Script for Atomicity:

```
-- rate_limit.lua  
local key = KEYS[1]  
local limit = tonumber(ARGV[1])  
local window = tonumber(ARGV[2])  
local current_time = tonumber(ARGV[3])  
  
-- Remove old entries  
redis.call('ZREMRANGEBYSCORE', key, 0, current_time - window)  
  
-- Get current count  
local count = redis.call('ZCARD', key)  
  
if count < limit then  
    -- Add new entry  
    redis.call('ZADD', key, current_time, current_time)  
    redis.call('EXPIRE', key, window)  
    return 1 -- Allowed  
else  
    return 0 -- Rate limited  
end
```

```

# Using Lua script in Python
RATE_LIMIT_SCRIPT = """
local key = KEYS[1]
local limit = tonumber(ARGV[1])
local window = tonumber(ARGV[2])
local current_time = tonumber(ARGV[3])

redis.call('ZREMRANGEBYSCORE', key, 0, current_time - window)
local count = redis.call('ZCARD', key)

if count < limit then
    redis.call('ZADD', key, current_time, current_time)
    redis.call('EXPIRE', key, window)
    return 1
else
    return 0
end
"""

class AtomicRateLimiter:
    def __init__(self, redis_client, limit: int, window_seconds: int):
        self.redis = redis_client
        self.limit = limit
        self.window = window_seconds
        self.script = self.redis.register_script(RATE_LIMIT_SCRIPT)

    def is_allowed(self, client_id: str) → bool:
        key = f"rate_limit:{client_id}"
        result = self.script(
            keys=[key],
            args=[self.limit, self.window, int(time.time())]
        )
        return result == 1

```

Solution 2: Token Bucket with Redis

```

import redis
import time

class DistributedTokenBucket:
    def __init__(self, redis_client, capacity: int, refill_rate: float):
        self.redis = redis_client
        self.capacity = capacity
        self.refill_rate = refill_rate # tokens per second

    def consume(self, client_id: str, tokens: int = 1) → bool:
        key = f"token_bucket:{client_id}"
        now = time.time()

        # Lua script for atomic token bucket
        script = """
local key = KEYS[1]
local capacity = tonumber(ARGV[1])
local refill_rate = tonumber(ARGV[2])
local tokens_requested = tonumber(ARGV[3])
local now = tonumber(ARGV[4])

local bucket = redis.call('HMGET', key, 'tokens', 'last_refill')
local current_tokens = tonumber(bucket[1]) or capacity
local last_refill = tonumber(bucket[2]) or now

-- Calculate tokens to add
local elapsed = now - last_refill
local tokens_to_add = elapsed * refill_rate
current_tokens = math.min(capacity, current_tokens + tokens_to_add)

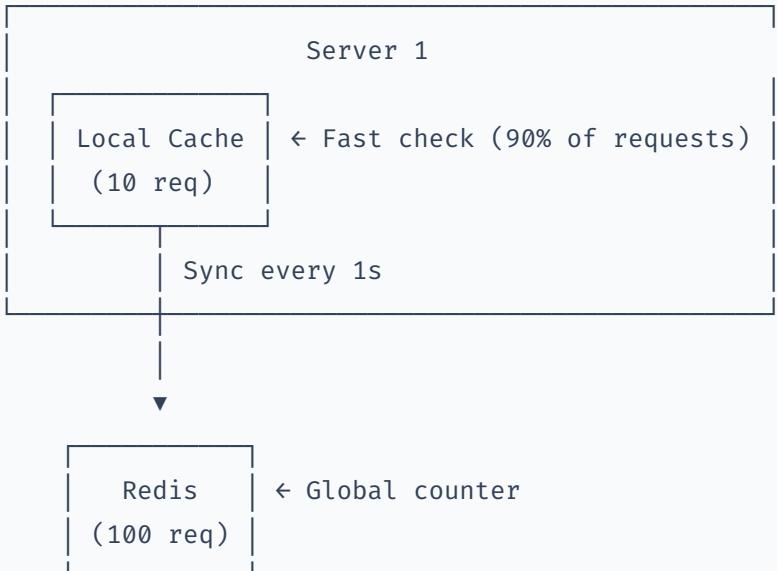
if current_tokens ≥ tokens_requested then
    current_tokens = current_tokens - tokens_requested
    redis.call('HMSET', key, 'tokens', current_tokens, 'last_refill',
now)
    redis.call('EXPIRE', key, 3600)
    return 1
else
    redis.call('HMSET', key, 'tokens', current_tokens, 'last_refill',
now)
    redis.call('EXPIRE', key, 3600)
    return 0
end
"""

```

```
"""
    result = self.redis.eval(
        script, 1, key,
        self.capacity, self.refill_rate, tokens, now
    )
    return result == 1
```

Solution 3: Local + Global Rate Limiting

Hybrid approach for reduced latency:



```

import time
import threading
from collections import defaultdict

class HybridRateLimiter:
    def __init__(self, redis_client, global_limit: int, local_limit: int,
                 window_seconds: int, sync_interval: float = 1.0):
        self.redis = redis_client
        self.global_limit = global_limit
        self.local_limit = local_limit
        self.window = window_seconds
        self.sync_interval = sync_interval

        self.local_counters = defaultdict(int)
        self.lock = threading.Lock()

        # Start sync thread
        self.sync_thread = threading.Thread(target=self._sync_loop,
                                            daemon=True)
        self.sync_thread.start()

    def is_allowed(self, client_id: str) -> bool:
        with self.lock:
            # Check local limit first (fast path)
            if self.local_counters[client_id] >= self.local_limit:
                return False

            self.local_counters[client_id] += 1
        return True

    def _sync_loop(self):
        while True:
            time.sleep(self.sync_interval)
            self._sync_to_redis()

    def _sync_to_redis(self):
        with self.lock:
            for client_id, count in list(self.local_counters.items()):
                if count > 0:
                    key = f"rate_limit:{client_id}"
                    self.redis.incrby(key, count)
                    self.redis.expire(key, self.window)

```

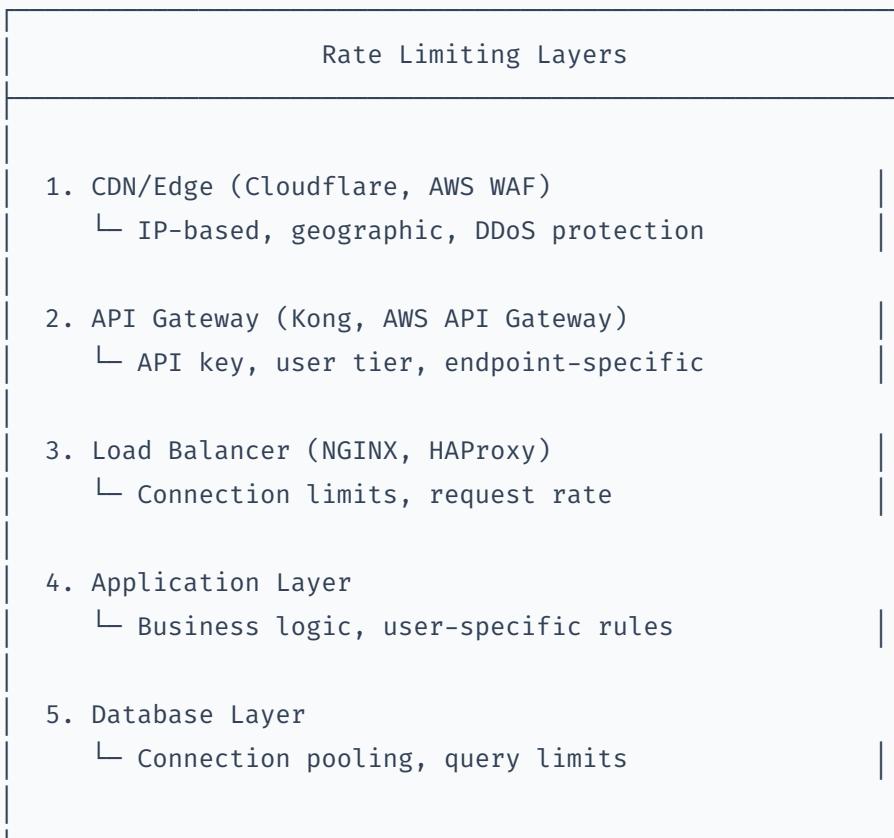
```

# Check global limit
global_count = int(self.redis.get(key) or 0)
if global_count > self.global_limit:
    # Reduce local limit temporarily
    self.local_limit = max(1, self.local_limit // 2)

self.local_counters.clear()

```

Rate Limiting at Different Layers



4. Implementation Patterns (10 min)

Pattern 1: API Gateway Rate Limiting

AWS API Gateway:

```
# serverless.yml
functions:
  api:
    handler: handler.main
    events:
      - http:
          path: /api/{proxy+}
          method: any
          throttling:
            burstLimit: 200
            rateLimit: 100
```

Kong Rate Limiting:

```
# kong.yml
plugins:
  - name: rate-limiting
    config:
      minute: 100
      hour: 1000
      policy: redis
      redis_host: redis.example.com
      redis_port: 6379
```

Pattern 2: Middleware Implementation

Express.js:

```

const rateLimit = require('express-rate-limit');
const RedisStore = require('rate-limit-redis');
const Redis = require('ioredis');

const redis = new Redis({
  host: 'localhost',
  port: 6379
});

// Basic rate limiter
const limiter = rateLimit({
  windowMs: 60 * 1000, // 1 minute
  max: 100, // 100 requests per minute
  standardHeaders: true,
  legacyHeaders: false,
  store: new RedisStore({
    sendCommand: (... args) => redis.call(... args),
  }),
  message: {
    error: 'Too many requests',
    retryAfter: 60
  }
});

// Tiered rate limiting
const tierLimits = {
  free: rateLimit({ windowMs: 60000, max: 10 }),
  pro: rateLimit({ windowMs: 60000, max: 100 }),
  enterprise: rateLimit({ windowMs: 60000, max: 1000 })
};

function tieredRateLimiter(req, res, next) {
  const tier = req.user?.tier || 'free';
  return tierLimits[tier](req, res, next);
}

app.use('/api/', tieredRateLimiter);

```

Python FastAPI:

```

from fastapi import FastAPI, Request, HTTPException
from slowapi import Limiter, _rate_limit_exceeded_handler
from slowapi.util import get_remote_address
from slowapi.errors import RateLimitExceeded

limiter = Limiter(key_func=get_remote_address)
app = FastAPI()
app.state.limiter = limiter
app.add_exception_handler(RateLimitExceeded, _rate_limit_exceeded_handler)

@app.get("/api/resource")
@limiter.limit("100/minute")
async def get_resource(request: Request):
    return {"data": "resource"}

# Custom key function (by API key)
def get_api_key(request: Request) → str:
    return request.headers.get("X-API-Key", get_remote_address(request))

@app.get("/api/premium")
@limiter.limit("1000/minute", key_func=get_api_key)
async def premium_endpoint(request: Request):
    return {"data": "premium resource"}

```

Pattern 3: Response Headers

Standard Rate Limit Headers:

```
HTTP/1.1 200 OK
X-RateLimit-Limit: 100
X-RateLimit-Remaining: 45
X-RateLimit-Reset: 1640000000
Retry-After: 30

# When rate limited
HTTP/1.1 429 Too Many Requests
X-RateLimit-Limit: 100
X-RateLimit-Remaining: 0
X-RateLimit-Reset: 1640000000
Retry-After: 30
Content-Type: application/json

{  
    "error": "rate_limit_exceeded",  
    "message": "Too many requests. Please retry after 30 seconds.",  
    "retry_after": 30
}
```

Implementation:

```

from fastapi import FastAPI, Request, Response
from fastapi.responses import JSONResponse


class RateLimitMiddleware:
    def __init__(self, app, limiter):
        self.app = app
        self.limiter = limiter

    async def __call__(self, scope, receive, send):
        if scope["type"] != "http":
            await self.app(scope, receive, send)
            return

        request = Request(scope, receive)
        client_id = self._get_client_id(request)

        allowed, info = self.limiter.check(client_id)

        if not allowed:
            response = JSONResponse(
                status_code=429,
                content={
                    "error": "rate_limit_exceeded",
                    "retry_after": info["retry_after"]
                },
                headers={
                    "X-RateLimit-Limit": str(info["limit"]),
                    "X-RateLimit-Remaining": "0",
                    "X-RateLimit-Reset": str(info["reset"]),
                    "Retry-After": str(info["retry_after"])
                }
            )
            await response(scope, receive, send)
            return

        # Add rate limit headers to successful responses
        async def send_with_headers(message):
            if message["type"] == "http.response.start":
                headers = dict(message.get("headers", []))
                headers[b"x-ratelimit-limit"] = str(info["limit"]).encode()
                headers[b"x-ratelimit-remaining"] =
str(info["remaining"]).encode()

    send_with_headers

```

```

        headers[b"x-ratelimit-reset"] = str(info["reset"]).encode()
        message["headers"] = list(headers.items())
        await send(message)

    await self.app(scope, receive, send_with_headers)

```

Pattern 4: Graceful Degradation

```

class GracefulRateLimiter:
    def __init__(self, redis_client, hard_limit: int, soft_limit: int):
        self.redis = redis_client
        self.hard_limit = hard_limit
        self.soft_limit = soft_limit

    def check(self, client_id: str) → tuple[str, dict]:
        """
        Returns:
        - 'allow': Request allowed
        - 'throttle': Request allowed but degraded
        - 'reject': Request rejected
        """
        count = self._get_count(client_id)

        if count < self.soft_limit:
            return 'allow', {'priority': 'high'}
        elif count < self.hard_limit:
            return 'throttle', {'priority': 'low', 'degraded': True}
        else:
            return 'reject', {'retry_after': 60}

    # Usage
    result, info = limiter.check("user_123")

    if result == 'allow':
        response = full_response()
    elif result == 'throttle':
        response = degraded_response() # Cached/simplified response
    else:
        raise RateLimitExceeded(info['retry_after'])

```

5. Best Practices & Real-World Examples (10 min)

Best Practices

1. Choose the Right Granularity

```
# Multiple rate limits for different concerns
RATE_LIMITS = {
    # Per-user limits
    'user_per_second': {'limit': 10, 'window': 1},
    'user_per_minute': {'limit': 100, 'window': 60},
    'user_per_day': {'limit': 10000, 'window': 86400},

    # Per-IP limits (for unauthenticated)
    'ip_per_minute': {'limit': 30, 'window': 60},

    # Per-endpoint limits
    'search_per_minute': {'limit': 20, 'window': 60},
    'upload_per_hour': {'limit': 10, 'window': 3600},

    # Global limits
    'global_per_second': {'limit': 10000, 'window': 1},
}
```

2. Implement Backoff Strategies

```
import time
import random

def exponential_backoff(attempt: int, base_delay: float = 1.0,
                        max_delay: float = 60.0) → float:
    """Calculate delay with exponential backoff and jitter"""
    delay = min(base_delay * (2 ** attempt), max_delay)
    jitter = random.uniform(0, delay * 0.1)
    return delay + jitter

def make_request_with_retry(url: str, max_retries: int = 5):
    for attempt in range(max_retries):
        response = requests.get(url)

        if response.status_code == 429:
            retry_after = int(response.headers.get('Retry-After', 0))
            delay = retry_after or exponential_backoff(attempt)
            print(f"Rate limited. Retrying in {delay:.2f}s")
            time.sleep(delay)
            continue

    return response

raise Exception("Max retries exceeded")
```

3. Monitor and Alert

```
import prometheus_client as prom

# Metrics
rate_limit_hits = prom.Counter(
    'rate_limit_hits_total',
    'Total rate limit hits',
    ['client_tier', 'endpoint']
)

rate_limit_remaining = prom.Gauge(
    'rate_limit_remaining',
    'Remaining requests in current window',
    ['client_id']
)

def check_rate_limit(client_id: str, endpoint: str) → bool:
    allowed, remaining = limiter.check(client_id)

    rate_limit_remaining.labels(client_id=client_id).set(remaining)

    if not allowed:
        tier = get_client_tier(client_id)
        rate_limit_hits.labels(client_tier=tier, endpoint=endpoint).inc()

    return allowed
```

4. Provide Clear Error Messages

```
def rate_limit_response(limit_info: dict) → dict:
    return {
        "error": {
            "code": "RATE_LIMIT_EXCEEDED",
            "message": "You have exceeded the rate limit for this endpoint.",
            "details": {
                "limit": limit_info["limit"],
                "window": f"{limit_info['window']} seconds",
                "retry_after": limit_info["retry_after"],
                "reset_at": limit_info["reset_timestamp"]
            },
            "documentation": "https://api.example.com/docs/rate-limits",
            "upgrade_url": "https://example.com/pricing"
        }
    }
```

Real-World Examples

GitHub API

Rate Limits:

- Unauthenticated: 60 requests/hour
- Authenticated: 5,000 requests/hour
- GitHub Apps: 15,000 requests/hour

Headers:

X-RateLimit-Limit: 5000
X-RateLimit-Remaining: 4999
X-RateLimit-Reset: 1372700873
X-RateLimit-Resource: core

Twitter API

Rate Limits (v2):

- App-level: 300 requests/15 min (tweets lookup)
- User-level: 900 requests/15 min (user timeline)

Response:

```
{  
  "title": "Too Many Requests",  
  "detail": "Too Many Requests",  
  "type": "about:blank",  
  "status": 429  
}
```

Stripe API

Rate Limits:

- Live mode: 100 requests/second
- Test mode: 25 requests/second

Special handling:

- Idempotency keys for safe retries
- Automatic retry with exponential backoff

AWS API Gateway

```
# Default limits  
Account-level: 10,000 requests/second  
Per-method: Configurable  
  
# Throttling response  
{  
  "message": "Rate exceeded"  
}  
Status: 429
```

Anti-Patterns to Avoid

DON'T:

- Rate limit without providing headers
- Use only IP-based limiting (NAT issues)
- Set limits too aggressively
- Forget to handle Redis failures
- Ignore burst requirements

DO:

- Provide clear rate limit headers
- Use multiple identifiers (user + IP)
- Start generous, tighten based on data
- Have fallback when Redis is down
- Allow reasonable bursts

Key Takeaways

1. **Rate limiting protects your system** from abuse, ensures fair usage, and maintains stability
2. **Choose the right algorithm** based on your needs - Token Bucket for bursts, Sliding Window for accuracy
3. **Distributed rate limiting requires coordination** - use Redis or similar shared storage
4. **Layer your rate limits** - CDN, API Gateway, Application, Database
5. **Provide good developer experience** - clear headers, error messages, and documentation
6. **Monitor and iterate** - track metrics and adjust limits based on real usage



Practical Exercise

Scenario: Design a rate limiting system for a public API with the following requirements:

Requirements: - Free tier: 100 requests/hour - Pro tier: 1,000 requests/hour - Enterprise tier: 10,000 requests/hour - Burst allowance: 2x limit for 10 seconds - Global limit: 50,000 requests/second across all users

Questions: 1. Which algorithm would you use? 2. How would you handle distributed rate limiting? 3. What headers would you return? 4. How would you handle Redis failures?

Suggested Solution:

Architecture:

Algorithm: Token Bucket (for burst support)
Storage: Redis Cluster (distributed)
Fallback: Local in-memory with sync

Rate Limits:

free:
capacity: 100
refill_rate: 100/3600 # ~0.028 tokens/sec
burst_capacity: 200

pro:
capacity: 1000
refill_rate: 1000/3600 # ~0.28 tokens/sec
burst_capacity: 2000

enterprise:
capacity: 10000
refill_rate: 10000/3600 # ~2.78 tokens/sec
burst_capacity: 20000

Global:

algorithm: Fixed Window Counter
limit: 50000/second

Headers:

- X-RateLimit-Limit
- X-RateLimit-Remaining
- X-RateLimit-Reset
- Retry-After (on 429)

Fallback Strategy:

- On Redis failure: Use local counter
- Sync to Redis when available
- Accept slightly higher limits during outage

Q&A Session

Time remaining for questions and discussion

Common Questions:

1. Token Bucket vs Leaky Bucket?

- Token Bucket: Allows bursts, good for APIs
- Leaky Bucket: Constant rate, good for background jobs

2. How to handle legitimate traffic spikes?

- Implement burst allowance
- Use adaptive rate limiting
- Consider queue-based throttling

3. Rate limiting in microservices?

- Centralized rate limiter service
- Or distributed with Redis
- Consider service mesh (Istio, Envoy)

4. What about WebSocket connections?

- Rate limit connection attempts
- Rate limit messages per connection
- Use sliding window for message rate

Session End - Thank You! 🎉

#rate-limiting #api-design #distributed-systems #architecture #session-notes