Investigating Impact of DDoS Attack and CPA Targeting CDN Caches

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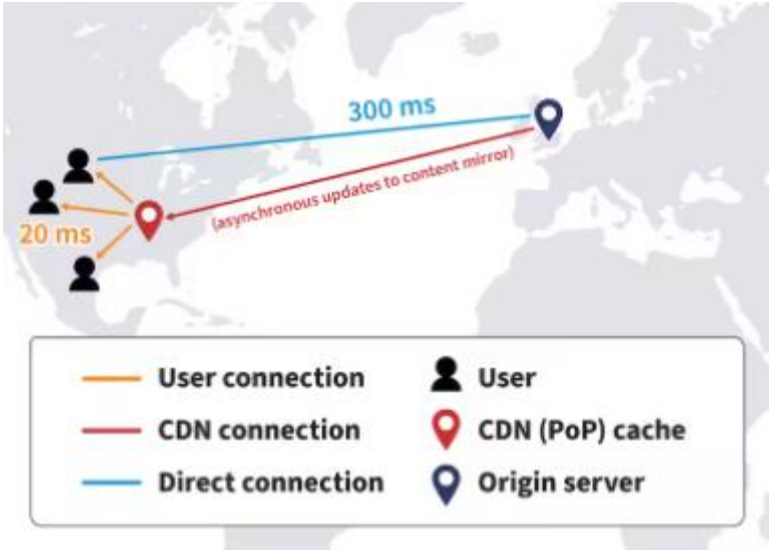
Content Delivery Network

- Content Delivery Network (CDN)
  - Origin servers: Provide the original version of the content
  - Cache servers: Cache the copy of contents, and they are responsible for delivering that content to nearby users.
  - DNS servers: Respond user's request with the name of a cache server from which the content can be served faster.

- The feature of CDN
  - Serves a large portion of the Internet content
  - Provides a faster and high-performance experience
  - Reduce bandwidth costs



Attacks targeting CDN

- Distributed denial-of-service (DDoS)
  - Disrupt the normal traffic of the targeted server, service or network by overwhelming the target with a flood of Internet traffic.

- Cache pollution attack（CPA）
  - Pollute the cache with low-popularity content to degrade the performance of the cache

Existing research

- There are many methods to prevent DDoS or CPA but there are no existing research investigating on DDoS and CPA on cache server.

- Knowing the attacker how to optimize the attack, CDN provider can better defend the attack.

Purpose of research

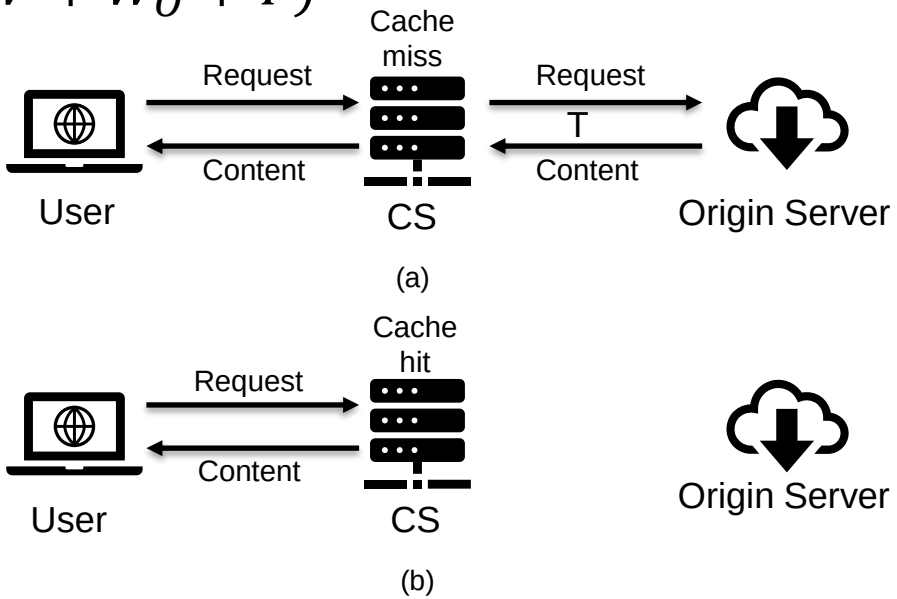
- Propose the analytical model to evaluate the impact of DDoS and CPA.
- Analyzes the impact of specific scenarios on DDoS and CPA
- Analyzes the influence of different factors on the attack
  - CDN providers can control factors to reduce the impact of attacks

Analytical Model

- M/M/1 queue
  - $W = \frac{1}{\mu - \sum_{i=1}^{M} \lambda_i}$

Parameter	Definition
W	Average response time
1/μ	Average service time
M	Number of contents
λ_i	Poisson arrival rate of request for content i
h_i	Cache hit ratio of content i

- Cache Server (CS)
  - The latency time T is spent when cache misses
  - $R(i) = h_i W + (1 - h_i)(W + W_O + T)$



Analytical Model

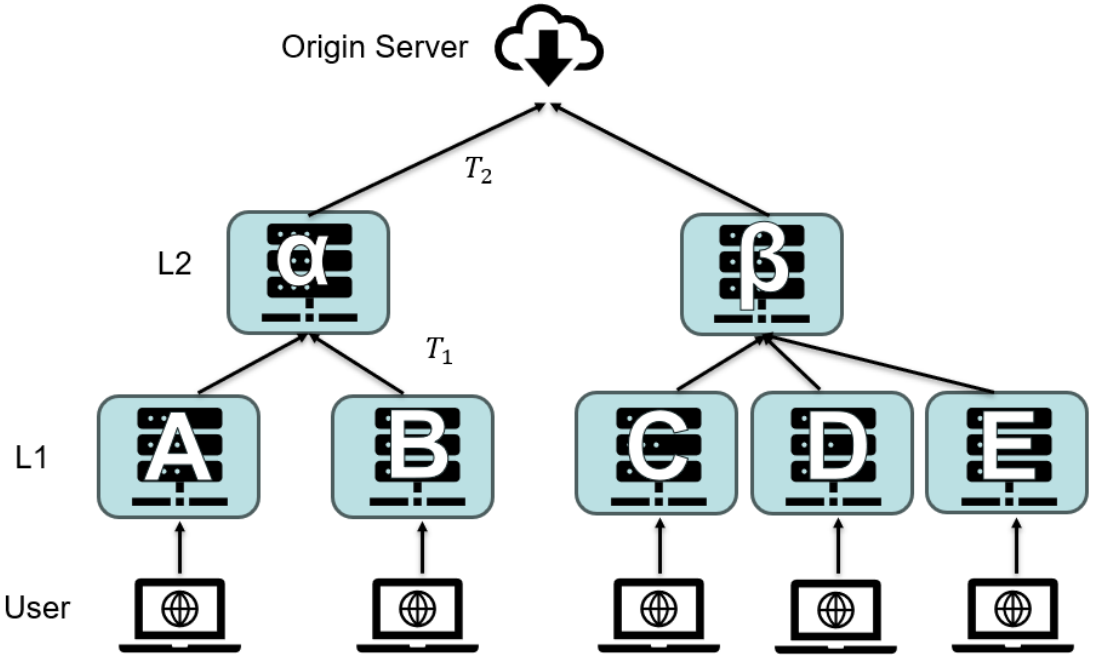
- Che-Approximation
  - $h_i \approx 1 - e^{-\lambda_i t_c}$
  - $\sum_{i=1}^{M} h_i = C$

Parameter	Definition
λ_i	Request rate of content i
C	Capacity of cache
t_c	Characteristic time

- The factor that affects average response time
  - Average service time（1/μ）
  - Arrival rate of request（λ）
  - Latency time (T)
  - Capacity of cache (C)

Multilayer CDN Model

- Multiple layer
  - Origin server provide the original version of the content
  - L2 CSes caches content from the origin server and connect to L1 CSes
  - L1 CSes caches content from L2 CSes and accommodate the user's request
  - All CSes adopt LRU



Multilayer CDN Model

- Average response time in CS A
  - $r_A = W_A$ -Cache hit in A
  - $r_\alpha = W_A + W_\alpha + T_1$ -Cache hit in α
  - $r_O = W_A + W_\alpha + W_O + T_1 + T_2$ -Cache miss in A and α
- Average response time of content i when request arrives at CS A
  - $R_A(i) = h_i^A r_A + (1 - h_i^A) h_i^\alpha r_\alpha + (1 - h_i^A)(1 - h_i^\alpha) r_O$
- Average response time of all requests in CS A
  - $R_A = \sum_{i=1}^{M} \frac{R_A(i)}{\lambda_A(i)}$

Evaluation: Simulation parameter

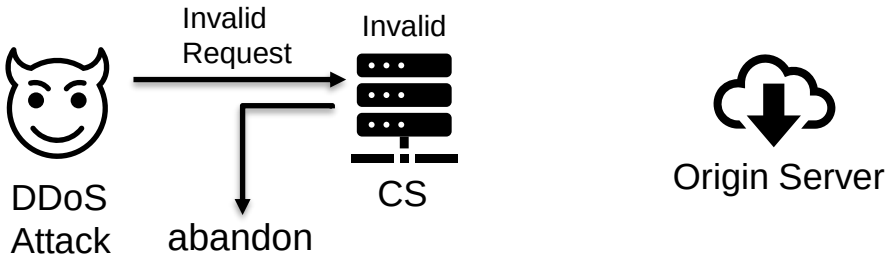
- Simulation parameter settings
  - Every CS has the same cache capacity (C)
  - Following the zip's law,

    λ_i = 80, 9, 6, 4, 1 in L1 CSes
  - The offered load of each CS is 50% without attack

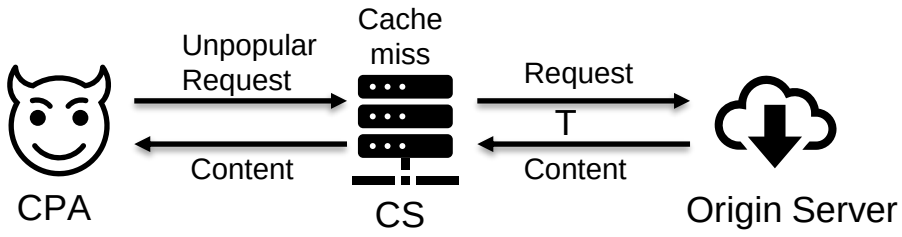
Parameter	Value
M	5
C	3
$\sum_{i=1}^{M} \lambda_i$	100 /s
1/μ of L1 CS	5ms
1/μ of CS α	5ms
1/μ of CS β	3.3ms
1/μ of origin server	3.3ms
T_1	50ms
T_2	30ms

Evaluation: Attack definition

- DDoS
  - Sends request packets to invalid contents that will increase the processing load of CSes and invalid contents are not stored in the CS

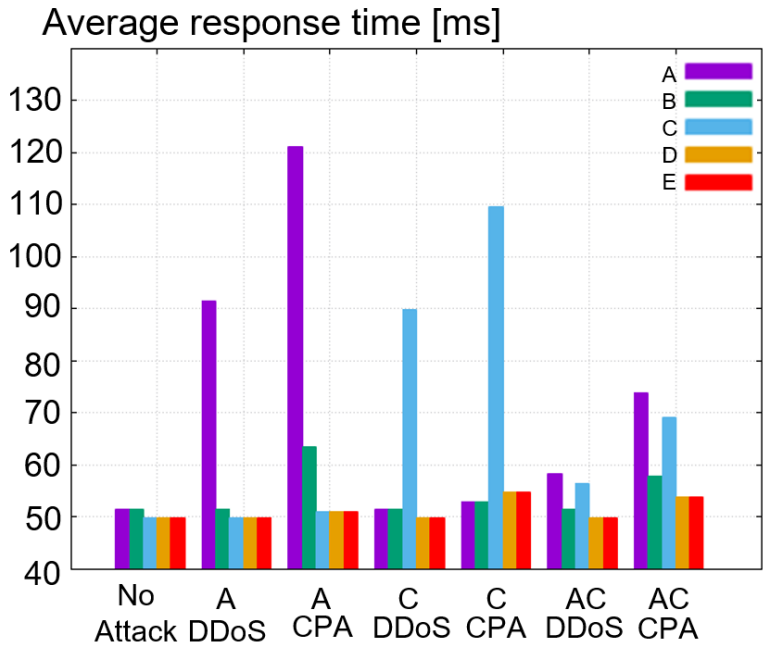


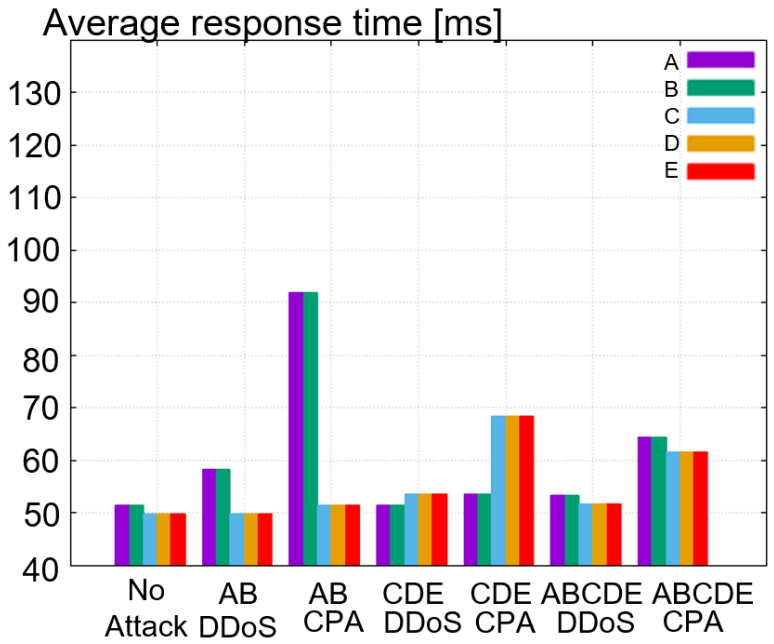
- CPA
  - Sends request packets to unpopular contents to decrease popular contents' cache hit ratio and increase the processing load



Evaluation: Attack with limited resources

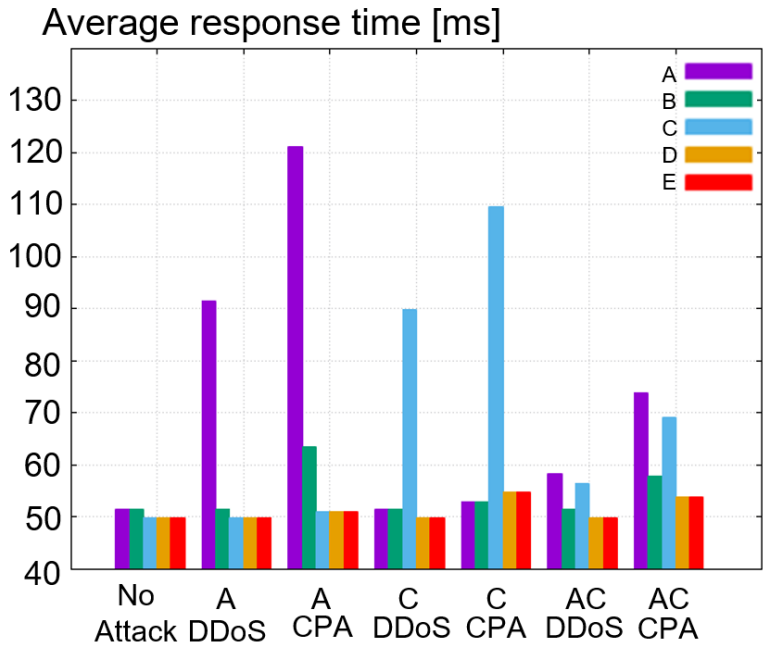
- Attack with limited resources
  - Assume that the attacker has limited resources to attack and set attacker's request rate 80/s
  - The attacker will assign requests to different CS
  - When the attacker sends request packets to multiple CSes, it equally sends packets among the CSes

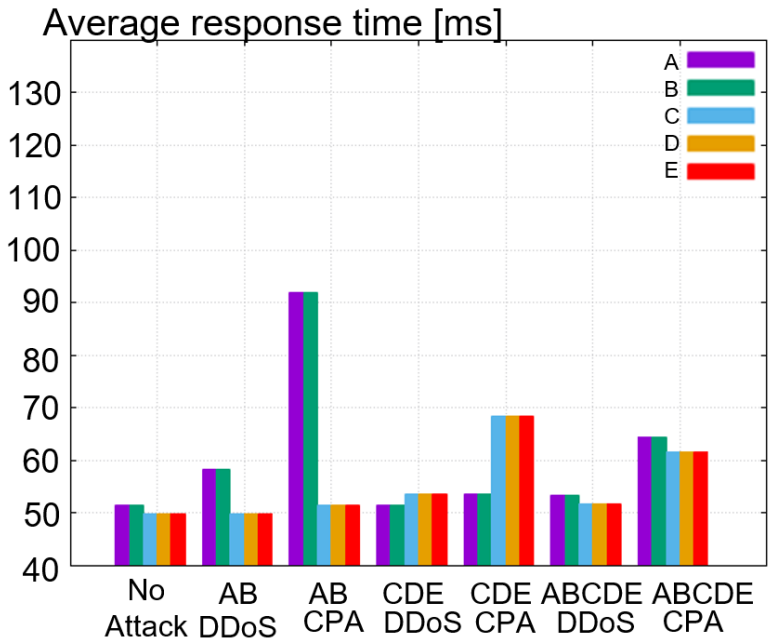




Evaluation: Attack with limited resources

- Evaluation
  - CPA largely increases the response time of CSes
  - CPA also increases the response time of other CSes
  - CPA is still effective when multiple CSes are attacked
    but DDoS attack has little effect because the resources are dispersed





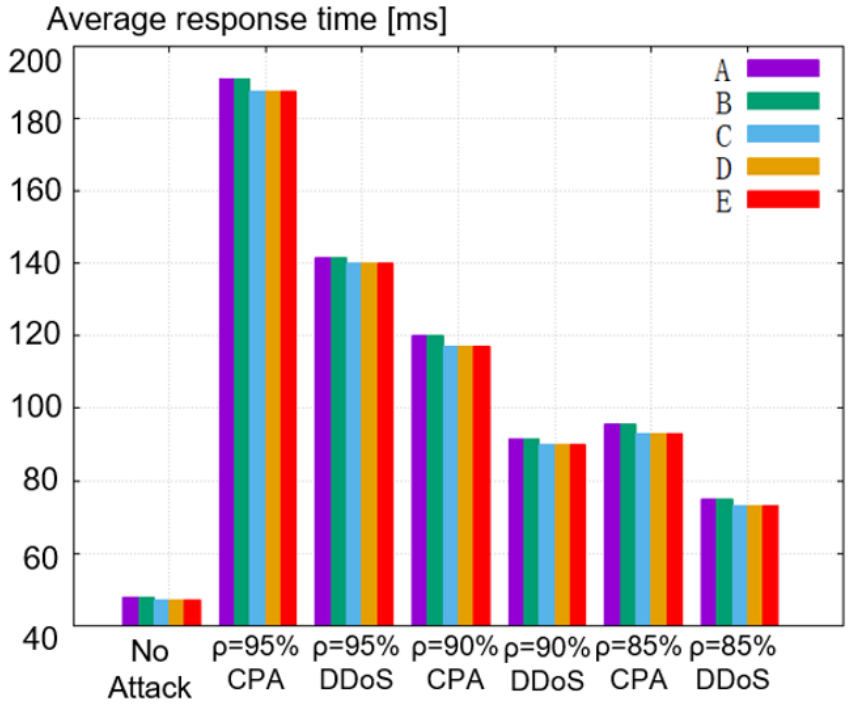
Evaluation: Attack under protection

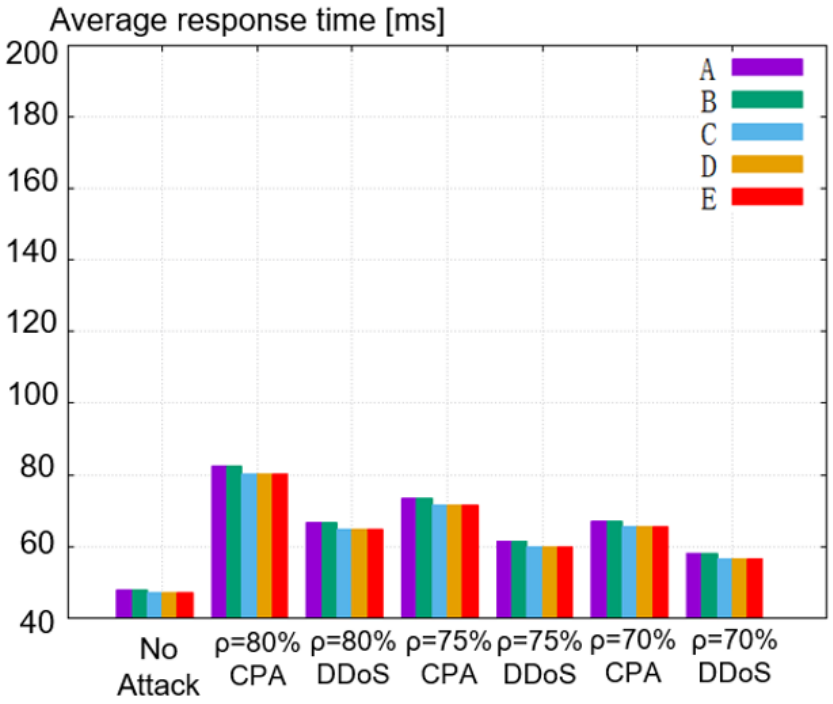
- Attack under protection mechanism
  - Assume CSes can bound the offered load of CSes below the threshold ρ even when DDoS or CPA occurs
  - Attacker will attack all CSes as much as possible
  - Reset the average service time in some CSes

Parameter	Value
1/μ of CS α	3.3ms
1/μ of CS β	2.2ms
1/μ of origin server	2.2ms

Evaluation: Attack under protection

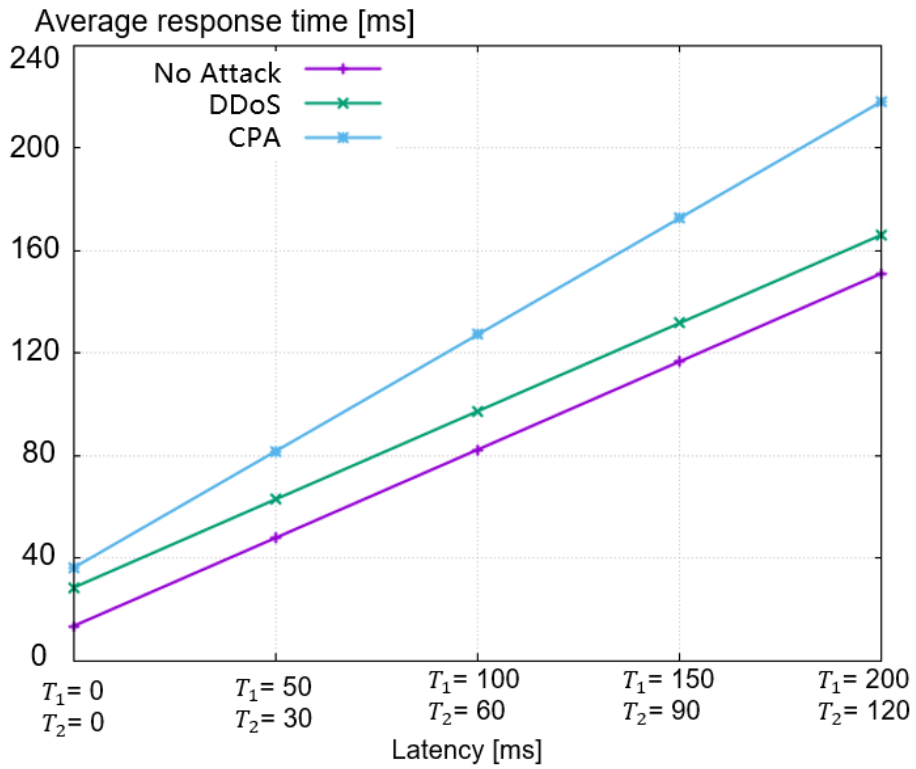
- Evaluation
  - Compared with case of DDoS attack, the CPA apparently increased the response time of CSes with the same ρ
  - When ρ becomes low, the effect of both attacks become weak, and the advantage of CPA also become weak.





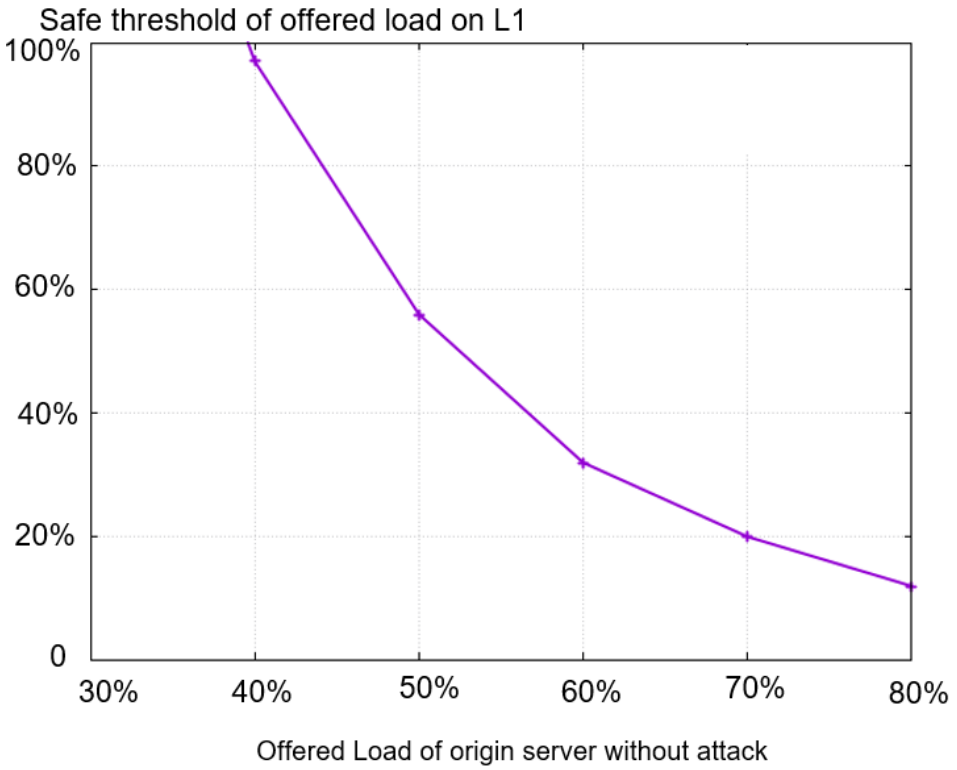
Evaluation Factors: Latency

- Latency
  - We obtained the average response time for different latency based on the attacks under protection
  - As the latency increased, the gap between CPA and DDoS attack became larger, indicating that CPA was sensitive to latency.



Evaluation Factors: Offered load

- Offered load
  - Safe threshold
    - The maximum offered load under the normal serve of the origin service
  - When the origin server load is less than 39%, safe threshold exceed 100%
  - As the offered load of origin server increases, the security threshold decreases sharply.



Conclusion and Future

- We used the M/M/1 queue model to derive the response time for CSes in CDN
- We built a multi-layer CDN model according to the actual CDN, and compared the response time under different attacks
- We investigated factors, and we revealed the potential threats in the multi-layer CDN model
- We are working on optimizing attack strategy with genetic algorithm to help CDN provider to reduce the impact of attack.