Measuring the efficiency of SDN mitigations against cyber attacks

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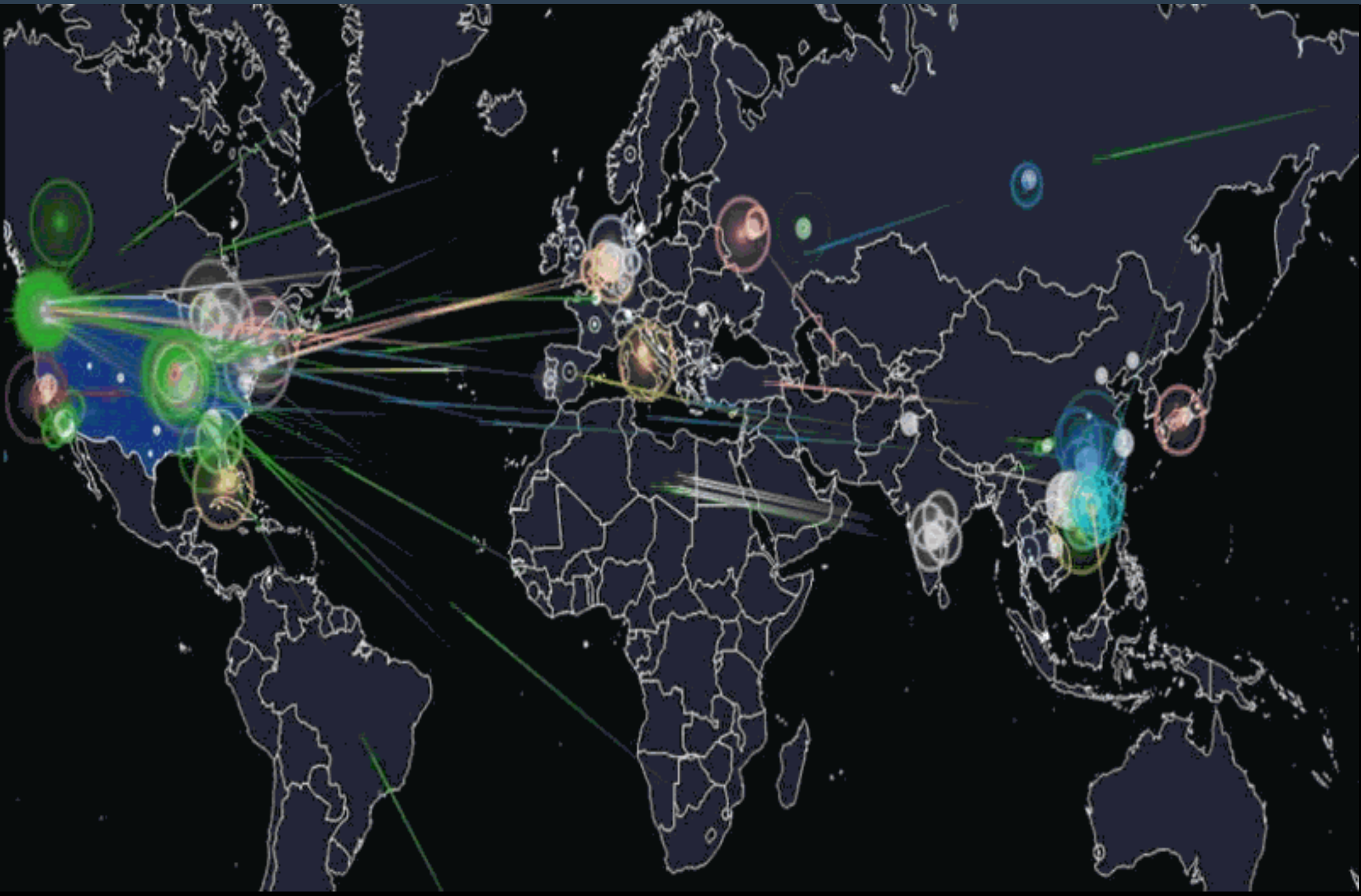
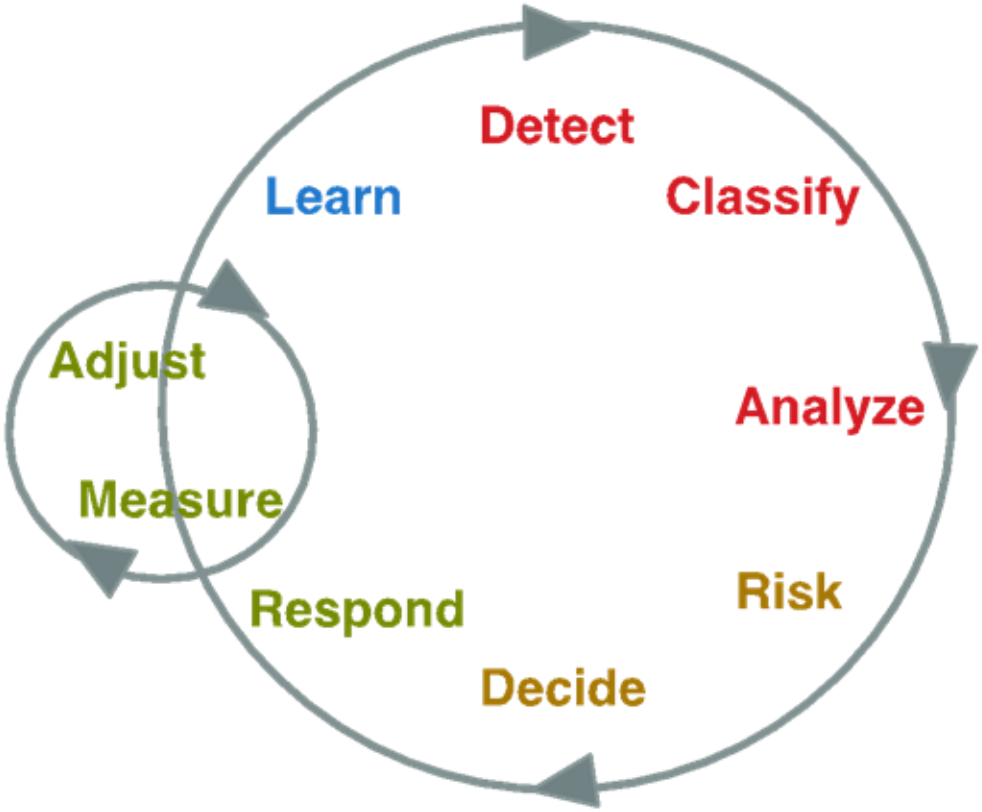
Context



SARNET Control loop



Detection phase: Detect, Classify, Analyze

Decision phase: Risk, Decide

Response phase: Respond, Adjust, Measure

Learn phase: Learn (with input from other phases)

Problem statement

Detect → ***Decide*** → **Respond**

There are multiple ways of responding to a single attack.

To select the right countermeasure the response phase executes:

- **Risk analysis** (we will omit this since we cannot quantify risk)
- **Response** selection

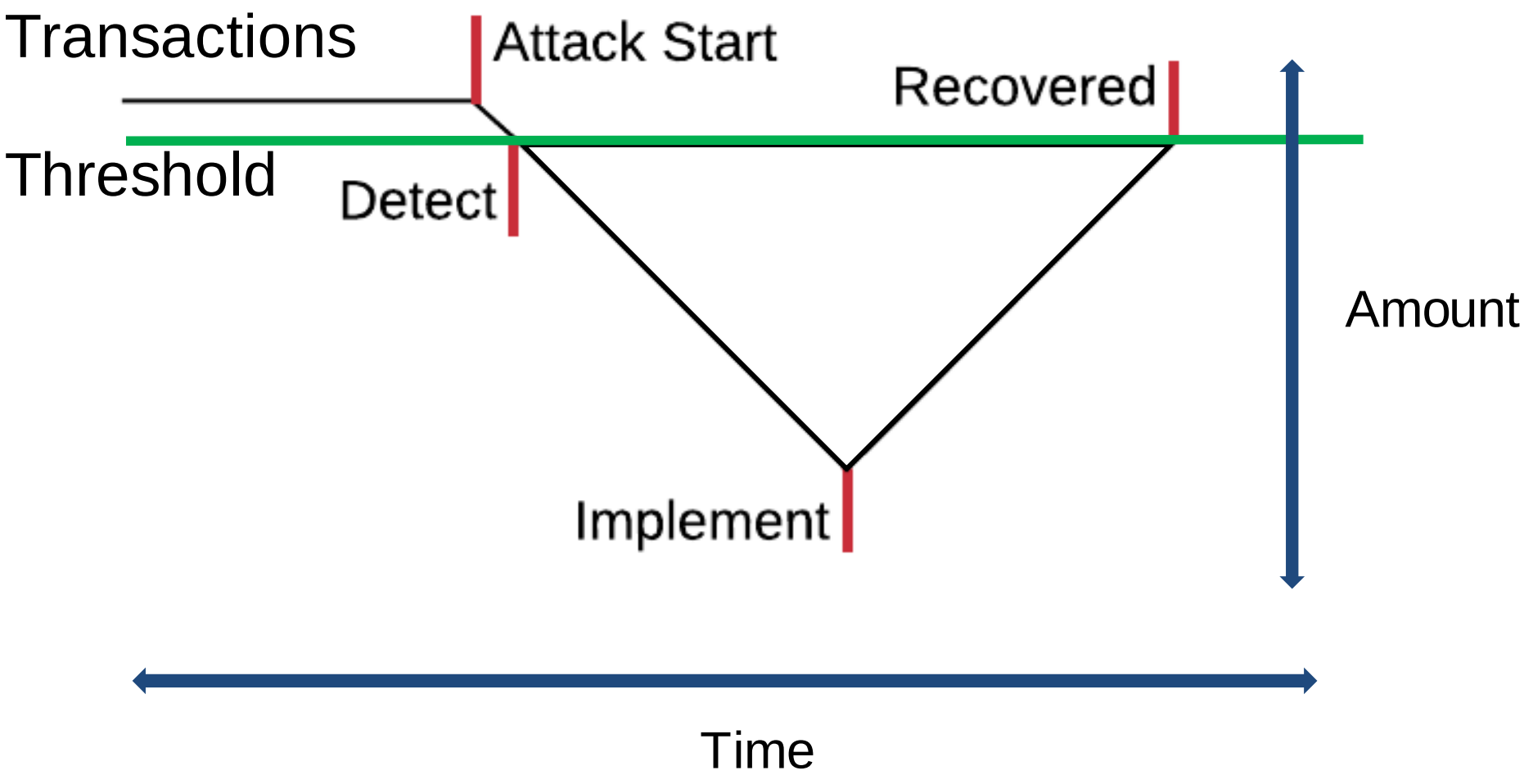
How does one pick the most effective countermeasure to defend against an attack?

Response selection

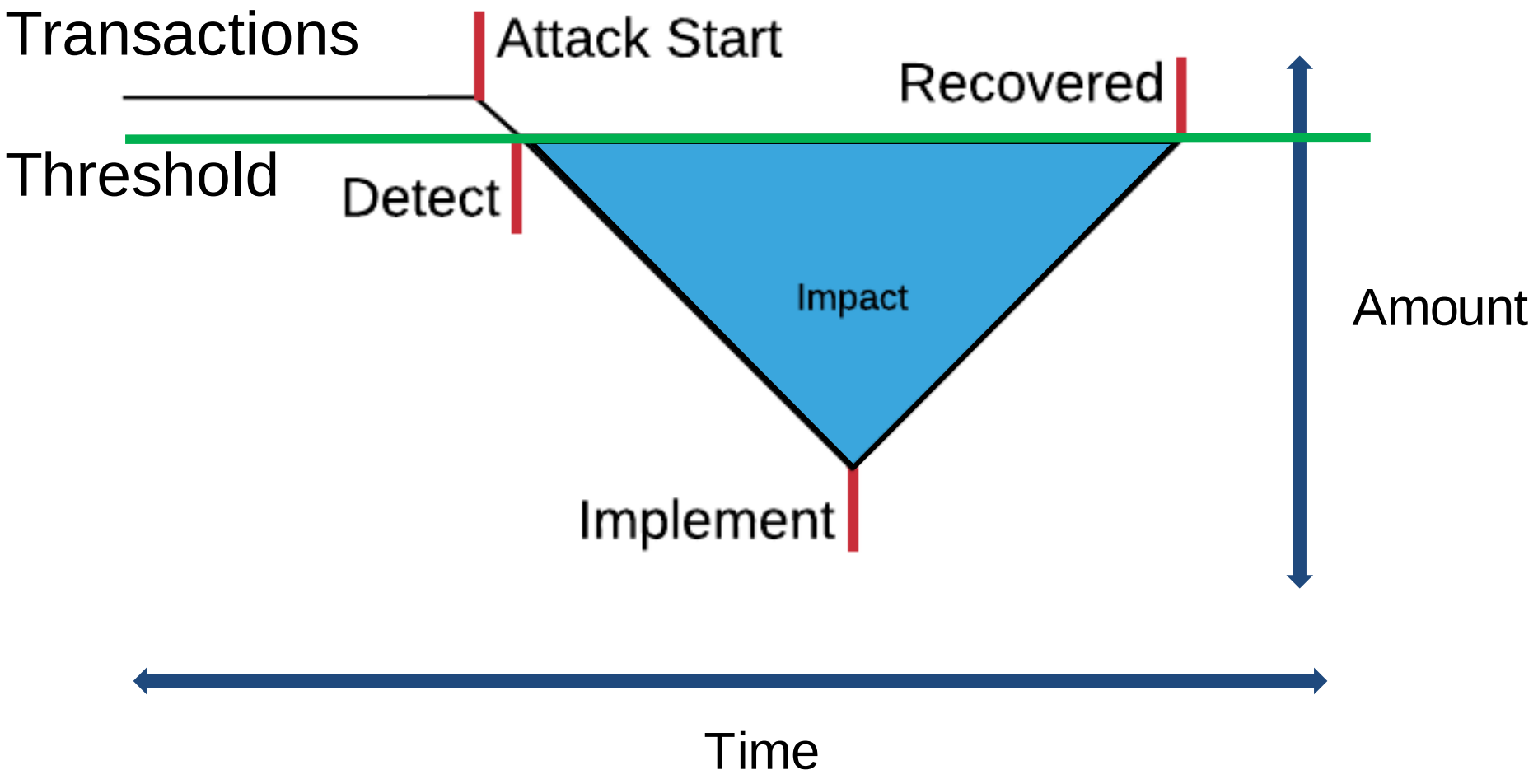
We can *rank* responses based on past behaviour. Therefore, we need a measure of the effect of the response.

- Success rate; did we recover?
- Response time; how fast did we recover?
- Impact; How much was lost?

Detection points and thresholds



Impact


Transactions
Attack Start
Recovered
Threshold
Detect
Impact
Amount
Implement
Time

Efficiency

Impact	I	Importance	α
Timeout	T	Not recovered boundary	β
Threshold (Baseline)	B	Cost integral	Ct
		Cost under normal circumstances	C

$$E(\text{recovered or not}, I, Ct) \triangleq \begin{cases} \beta + \alpha\frac{B\cdot T - I}{B\cdot T} + (1-\beta-\alpha)\frac{C\cdot T - Ct}{C\cdot T} & \\ = 1 - \frac{\alpha}{B\cdot T}I - \frac{1-\beta-\alpha}{C\cdot T}Ct & \text{Recovered,} \\ \alpha(\frac{\beta}{1-\beta})\frac{B\cdot T - I}{B\cdot T} + (1-\beta-\alpha)(\frac{\beta}{1-\beta})\frac{C\cdot T - Ct}{C\cdot T} & \\ = \beta - \alpha\frac{\beta}{(1-\beta)(B\cdot T)}I - (1-\beta-\alpha)\frac{\beta}{(1-\beta)(C\cdot T)}Ct & \text{otherwise,} \end{cases}$$

Because we have no cost measurements we will ignore cost for now.

$\beta = 0, \quad \alpha \approx 1$

We are only interested in the 'Recovered' situation

Efficiency

Impact I
Timeout T
Threshold (baseline) B

Success rate S
Weight (Importance of metric) γ

Efficiency single metric:

$$E_m(recovered, I) \triangleq 1 - \frac{I}{B * T}$$

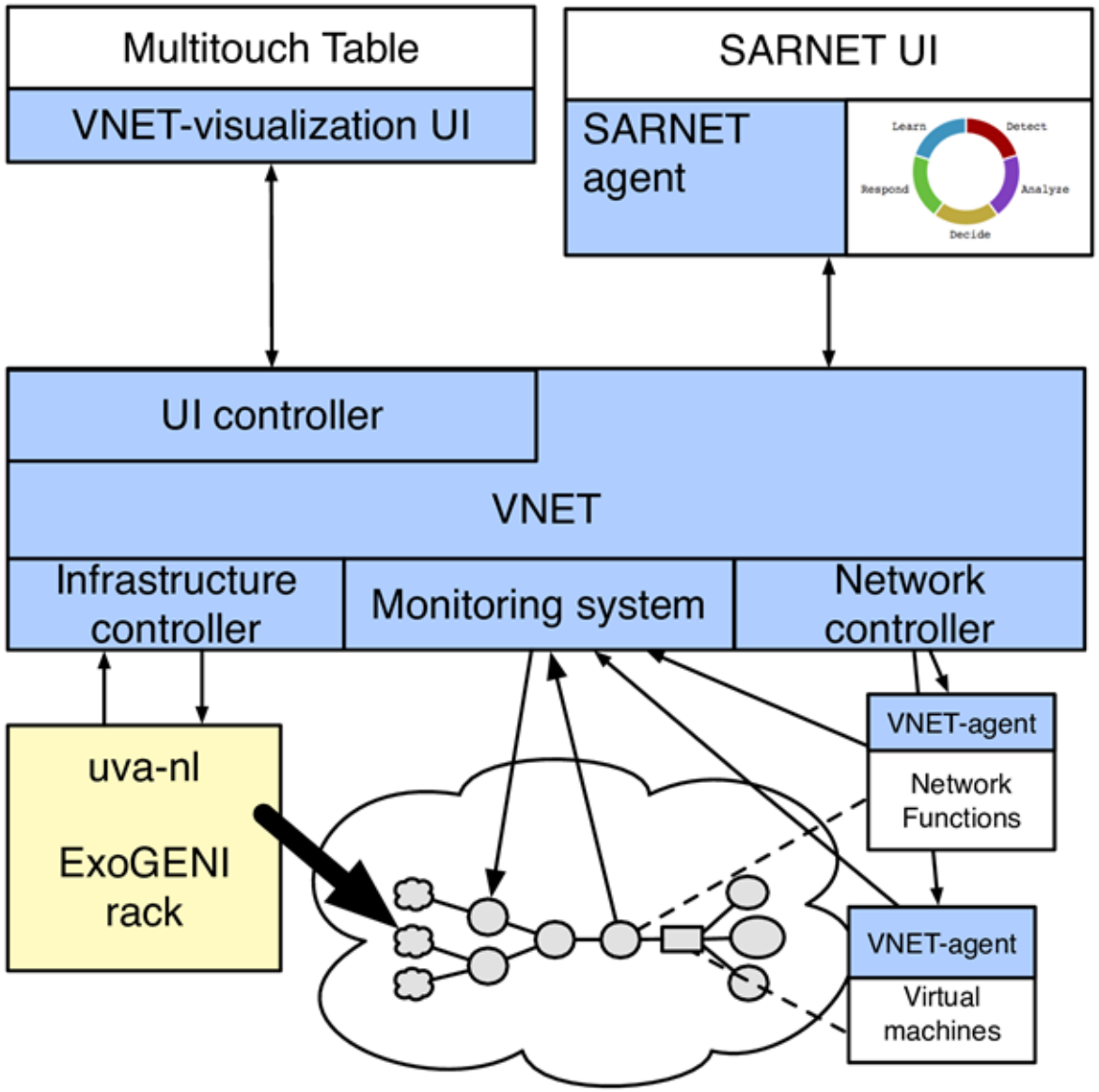
Efficiency defence:

$$E_d \triangleq \sum_{i=1}^{n} \gamma_i E_{m,i}$$

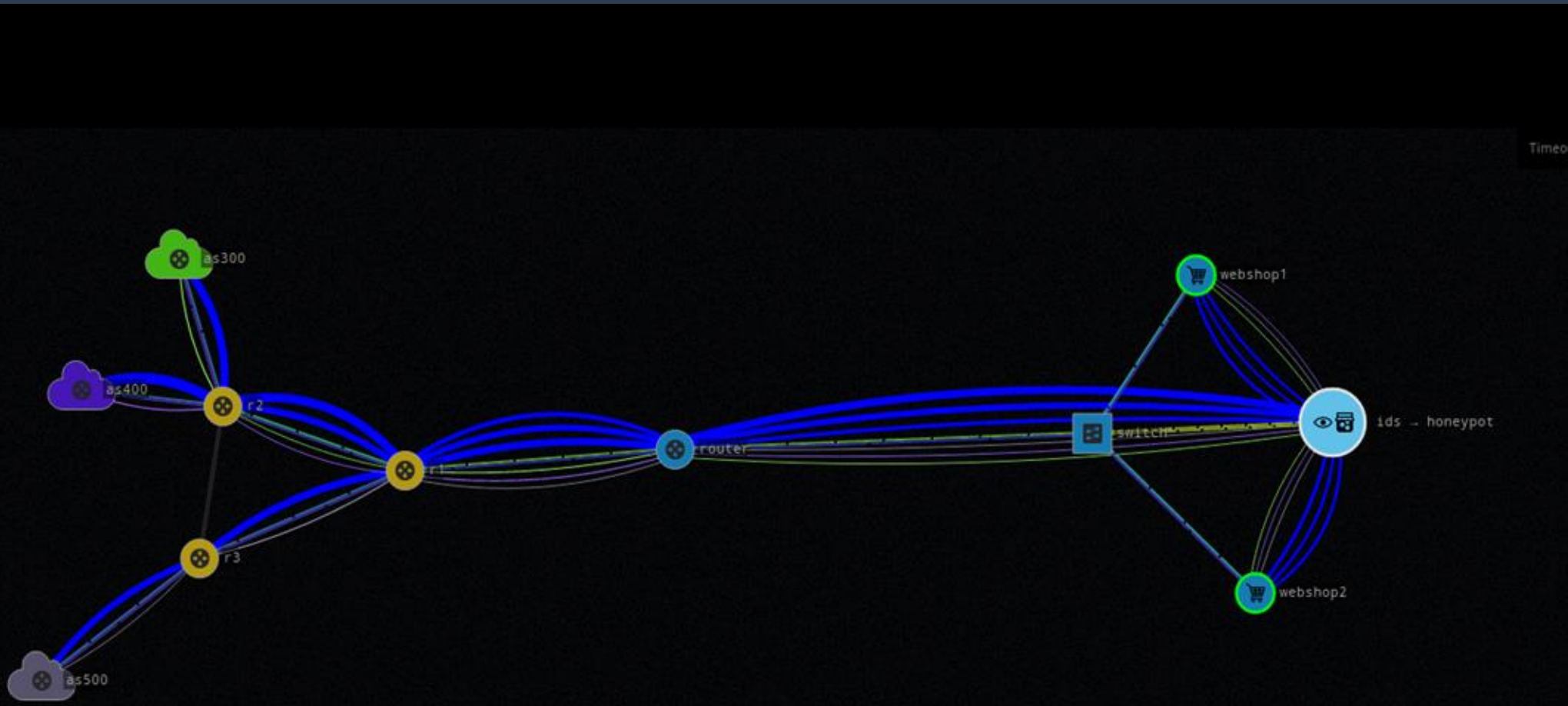
Efficiency countermeasure:

$$E_c \triangleq S_c * E_d$$

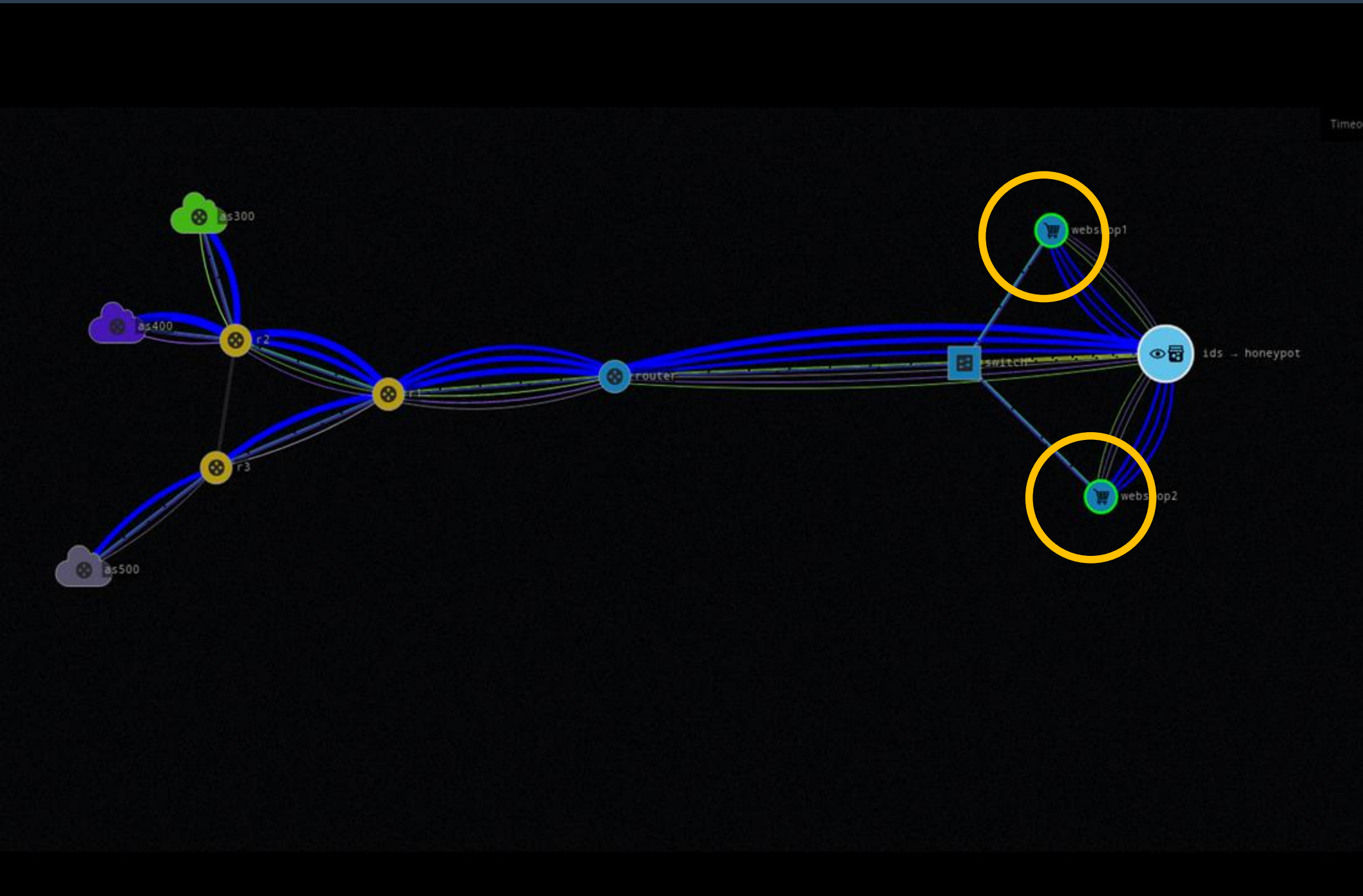
Environment



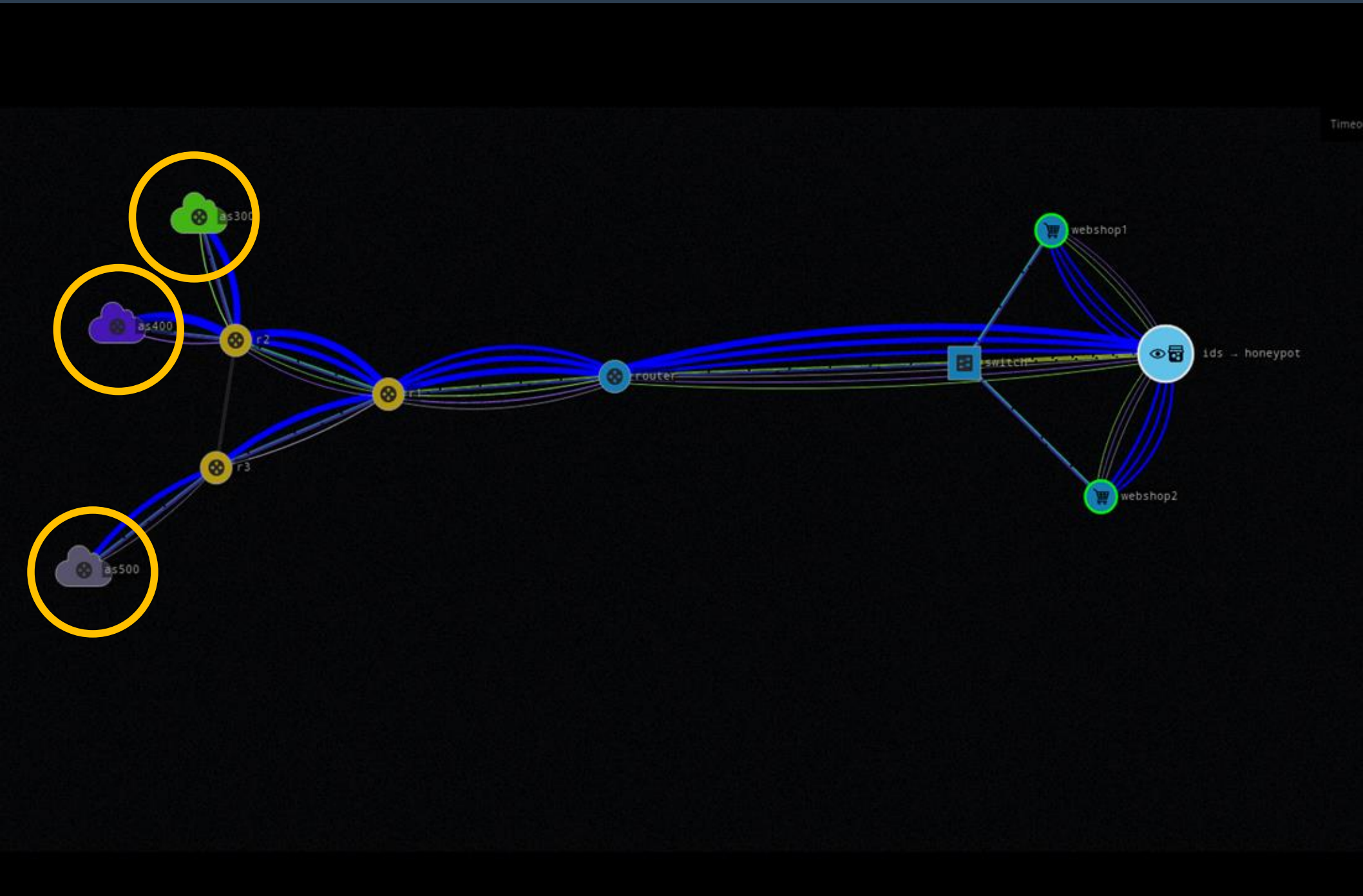
Scenario


as300
as400
as500
r2
r1
r3
router
switch
webshop1
webshop2
ids → honeypot

Scenario



Scenario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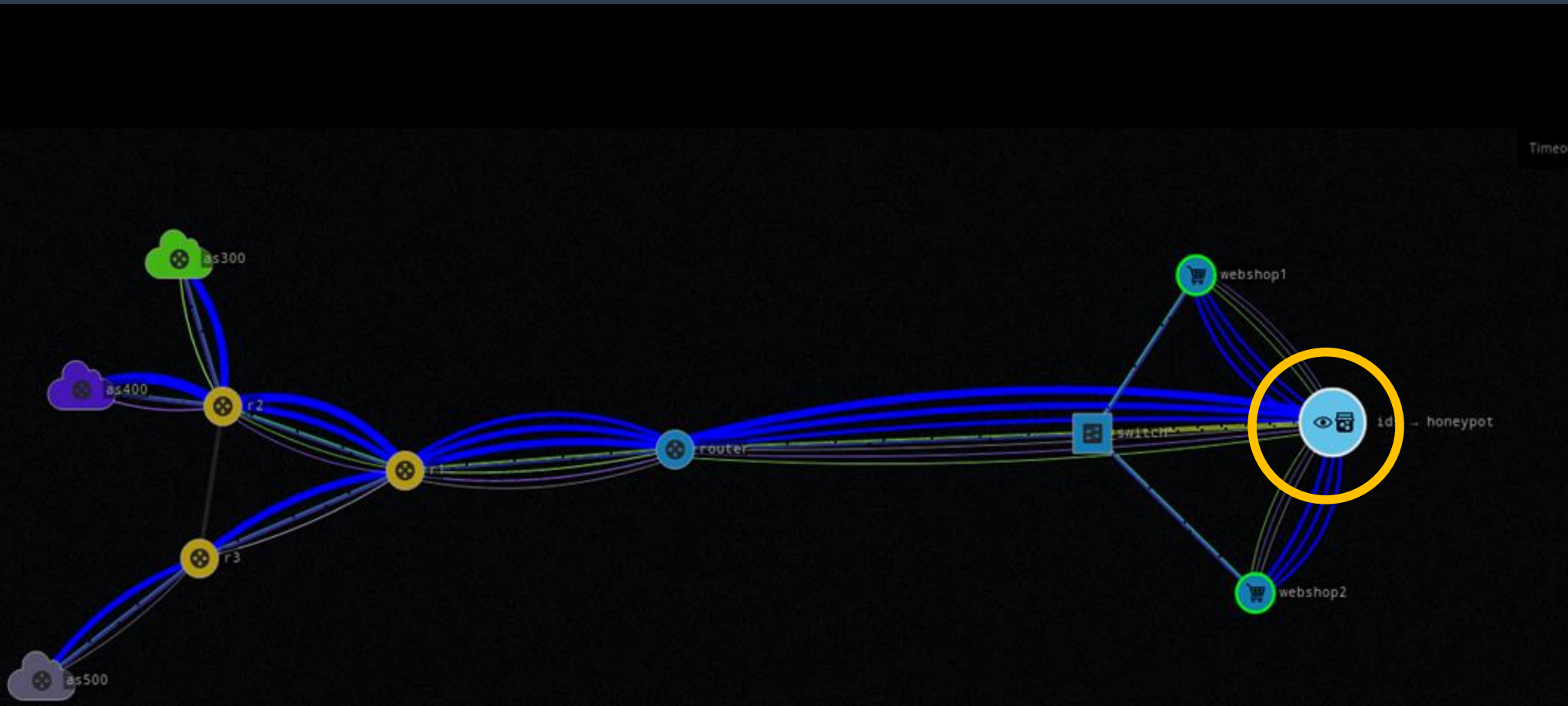
Scenario


as300
as400
as500
r2
r1
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router
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Observables

Metrics

Sales: the combined amount of transactions to web services
CPU: combined CPU load on the web services
logfail: The amount of failed logins

Attack classifications

DDoS_Attack	UDP based DDoS attack causes link congestion	if not *Sales* > 210
pwd_bf_attack	Password brute force attack causes abnormal login failures	if not *logfail*< 20
CPU_Attack	DoS attack focused on consuming CPU resources.	if not *CPU* < 85 and not *Sales* < 210

Experiments

Each measurement is repeated 50 times.

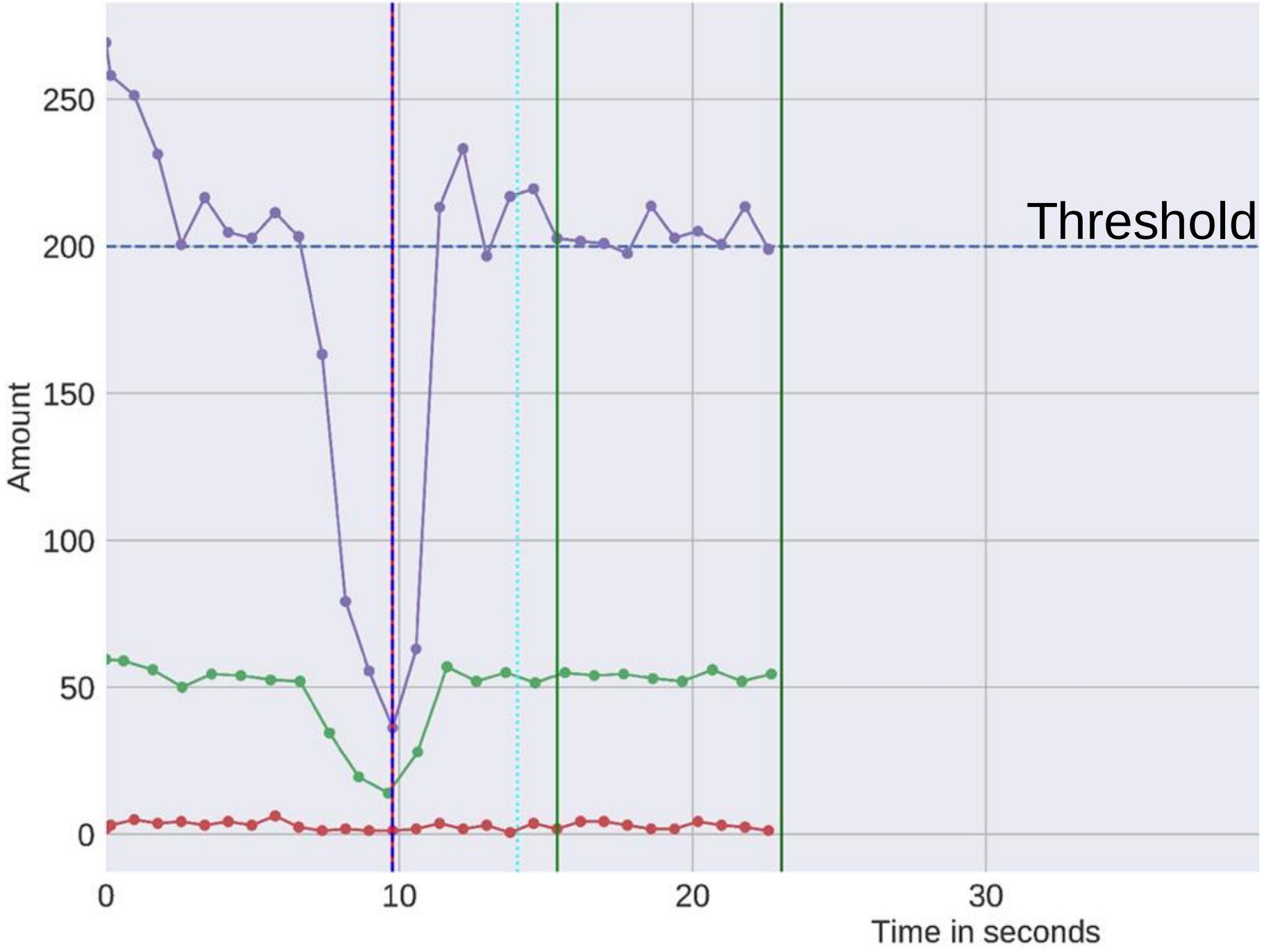
We vary the following parameters:

- Response timeout: 30-40-60s
- Attack size: Light, Medium, Heavy

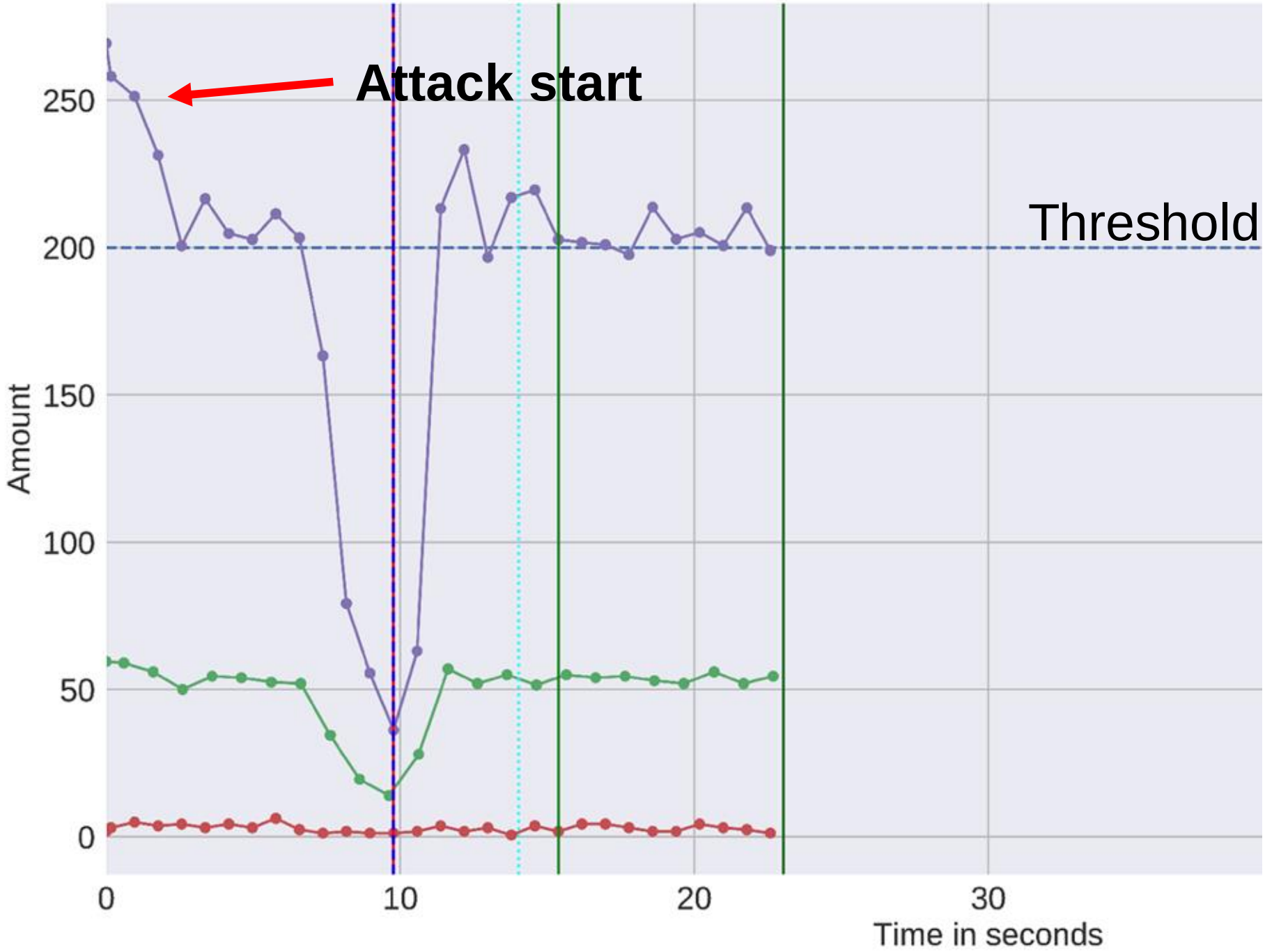
The recorded values are *averaged* over a moving window of 10 samples.

For impact we use a ceiling of 2 * threshold to prevent the impact of unbounded metrics from growing out of scale towards infinity.

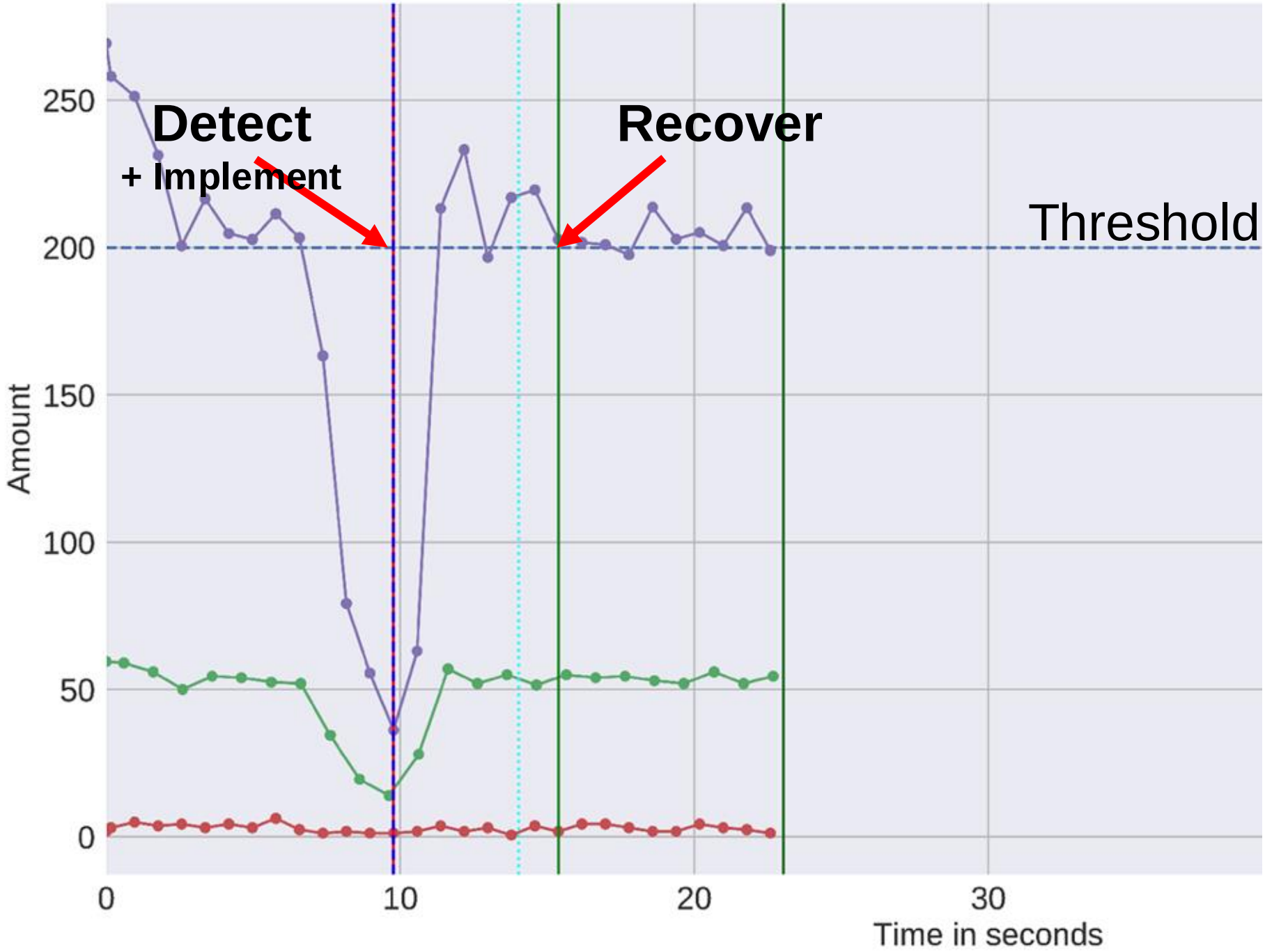
Example: DDos attack



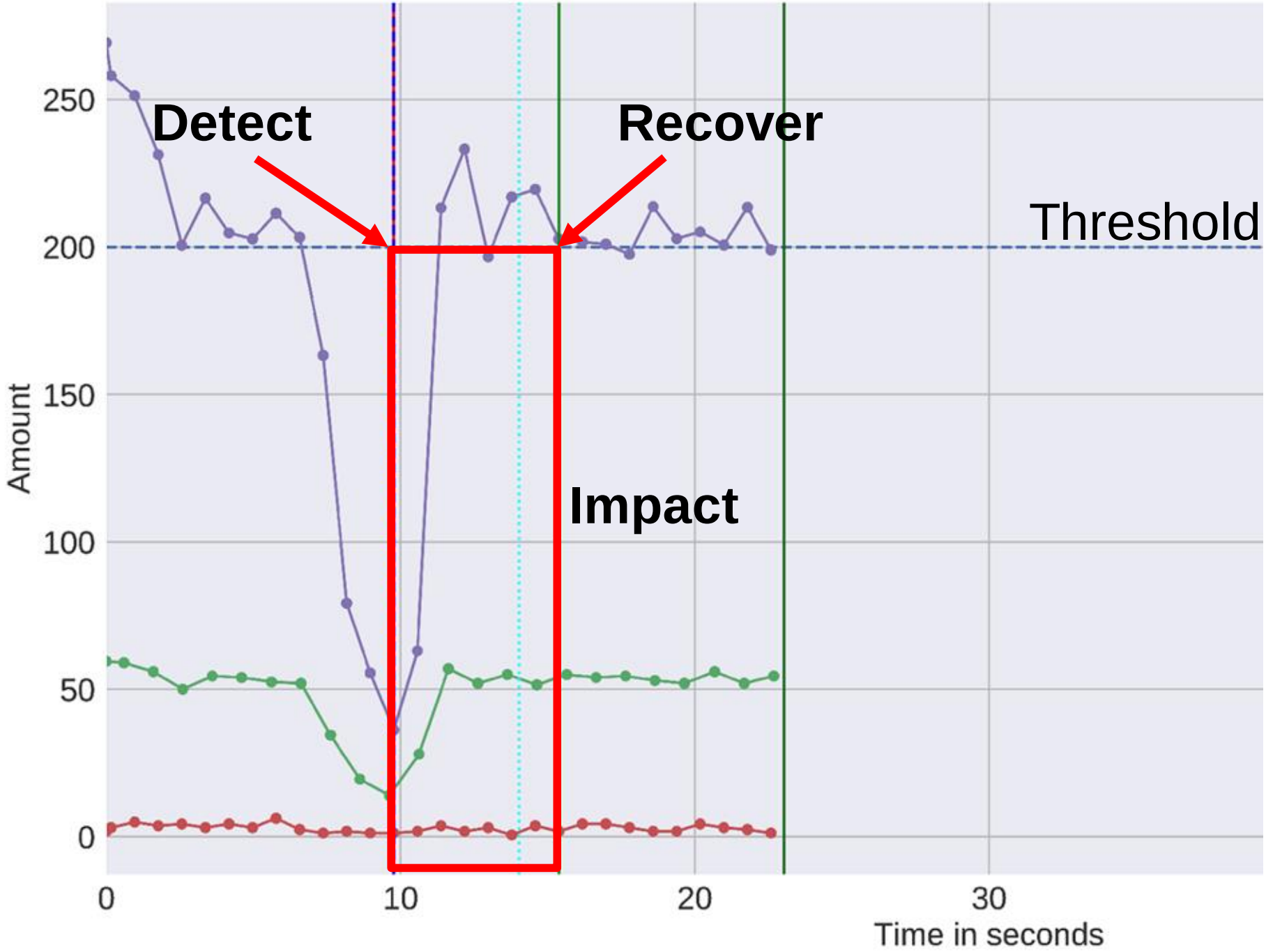
Example: DDos attack



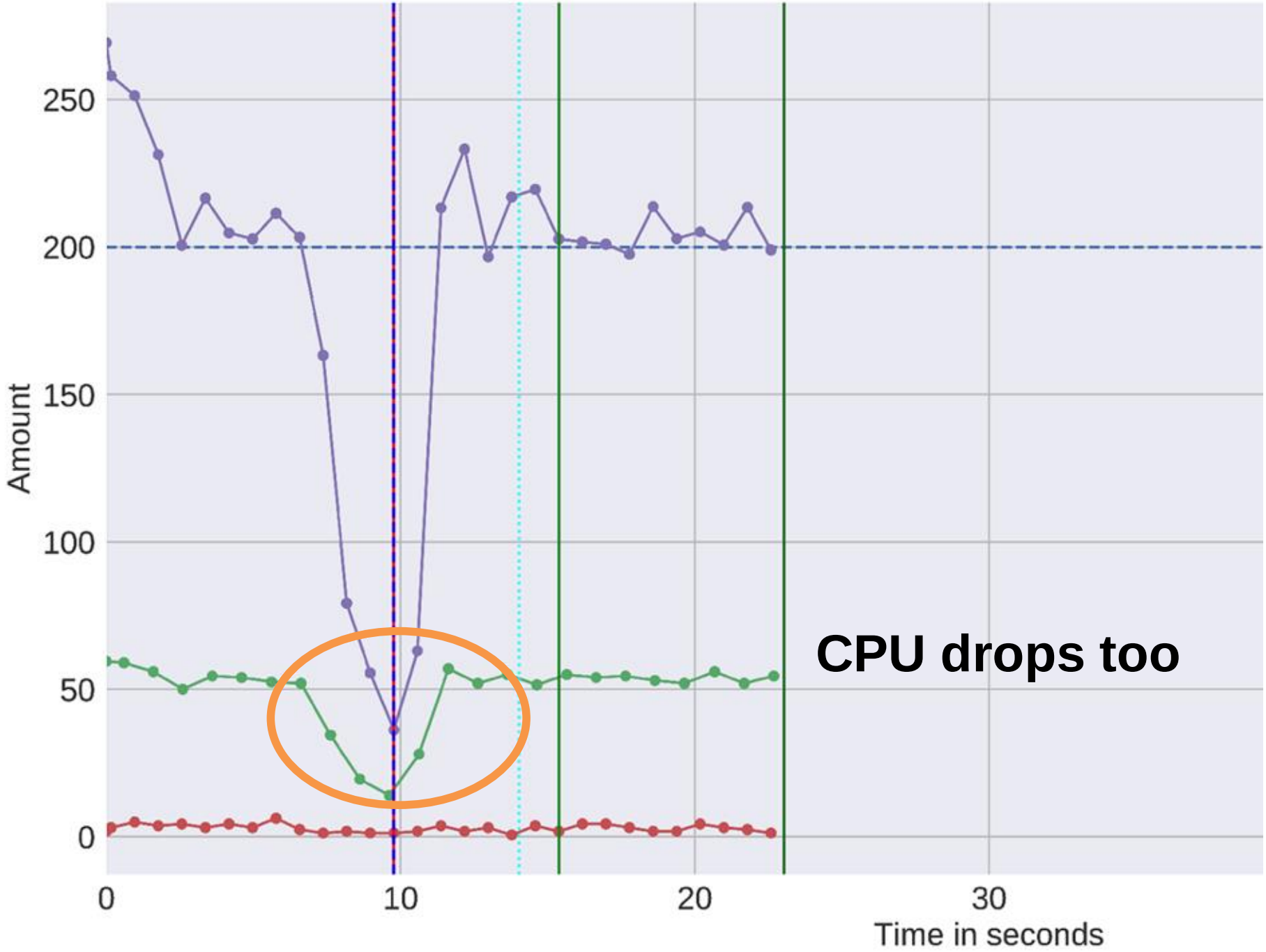
Example: DDos attack



Example: DDos attack



Example: DDos attack (Bonus)



Success rate

Defence success rate in % (50 attempts)

Attack	Defence		Size	
		Light	Medium	Heavy
CPU_attack	***captcha***	68	10	0
	honeypot	100	100	100
	udp-filter	0	0	0
	udp-rateup	0	0	0
pwd_bf_attack	***captcha***	100	100	100
	honeypot	100	100	100
	udp-filter	0	0	0
	udp-rateup	0	0	0
DDoS_attack	***captcha***	0	0	0
	honeypot	6	0	0
	udp-filter	100	100	100
	udp-rateup	64	0	0

Success rate

Defence success rate in % (50 attempts)

Attack	Defence		Size	
		Light	Medium	Heavy
CPU_attack	***captcha***	68	10	0
	honeypot	100	100	100
	udp-filter	0	0	0
	udp-rateup	0	0	0
pwd_bf_attack	***captcha***	100	100	100
	honeypot	100	100	100
	udp-filter	0	0	0
	udp-rateup	0	0	0
DDoS_attack	***captcha***	0	0	0
	honeypot	6	0	0
	udp-filter	100	100	100
	udp-rateup	64	0	0

Success rate

Defence success rate in % (50 attempts)

Attack	Defence		Size	
		Light	Medium	Heavy
CPU_attack	***captcha***	68	10	0
	honeypot	100	100	100
	udp-filter	0	0	0
	udp-rateup	0	0	0
pwd_bf_attack	***captcha***	100	100	100
	honeypot	100	100	100
	udp-filter	0	0	0
	udp-rateup	0	0	0
DDoS_attack	***captcha***	0	0	0
	honeypot	6	0	0
	udp-filter	100	100	100
	udp-rateup	64	0	0

Success rate

Defence success rate in % (50 attempts)

Attack	Defence		Size	
		Light	Medium	Heavy
CPU_attack	***captcha***	68	10	0
	honeypot	100	100	100
	udp-filter	0	0	0
	udp-rateup	0	0	0
pwd_bf_attack	***captcha***	100	100	100
	honeypot	100	100	100
	udp-filter	0	0	0
	udp-rateup	0	0	0
DDoS_attack	***captcha***	0	0	0
	honeypot	6	0	0
	udp-filter	100	100	100
	udp-rateup	64	0	0

Efficiency

Efficiency of countermeasures
(50 attempts)

Attack	Defence		Size	
		Light	Medium	Heavy
CPU_attack	***captcha***	0.44	0.04	0.00
	honeypot	0.98	0.98	0.97
pwd_bf_attack	***captcha***	0.94	0.94	0.94
	honeypot	0.94	0.94	0.94
DDoS_attack	***udp-filter***	1.00	1.00	0.99
	udp-rateup	0.35	0.00	0.00

Ranking defences

Based on the defence efficiency a SARNET will make the following choices

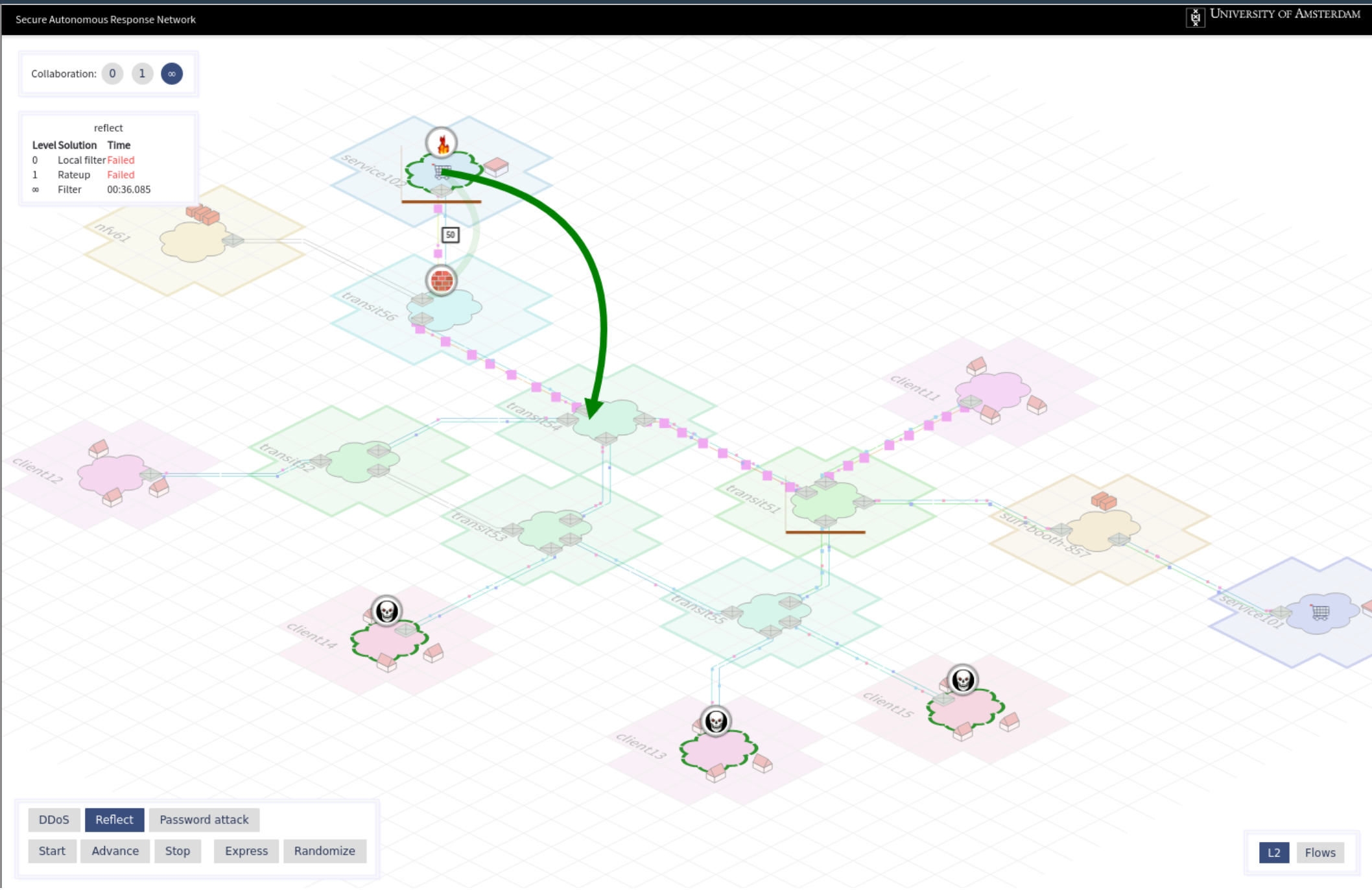
	First choice	**Second choice**
CPU_attack	captcha	honeypot
pwd_bf_attack	honeypot/captcha	-
DDoS_attack	udp-filter	-
DDoS_attack **(light)**	udp-filter	udp-rateup

Conclusions

Determining efficiency is a first step towards ranking countermeasures and self learning.

Efficiency is *universal* enough to apply and compare on new countermeasures.

Current work: multi-domain



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