Computer Security: A Signaling Game Approach

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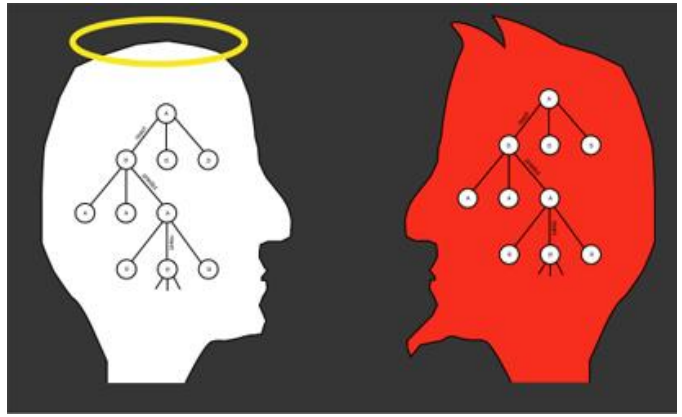
Hard to Differentiate Attacks

Signature Based Detection → Variations of Attacks → Anomaly Based Detection

Anomaly Based Detection → Reduce the **significance of abnormality**

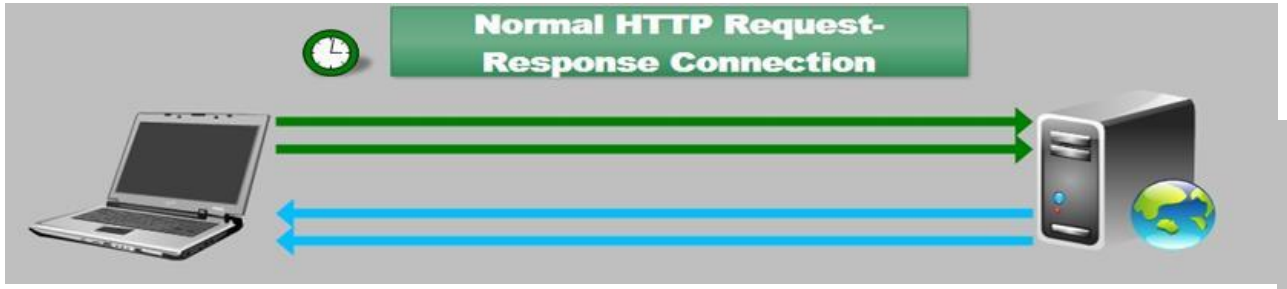


Increased
FALSE NEGATIVE and
FALSE POSITIVE rate

Can a game theoretic **'RATIONAL DECISION MAKING'** contribute?

Example: slowHTTP based DoS

- Traditional DoS on the **NETWORK** layer
- Exploits the **APPLICATION LAYER**
  - ***Silent & Small:*** *No significant trace* to determine malicious intention
  - Less resources required for equivalent impact
- Said that it can **EASILY** be prevented with <u>appropriate the server configuration</u>
- *E.g., slow HTTP GET, slow HTTP POST, slow HTTP header*



incomplete request

Limitations for Security

- Often said that it can **EASILY** be prevented with appropriate the server configuration

However,

- **limited control** over each machine:
  Cannot assure that all applications are hardened.

Need for a method to handle the attack without control over all servers

Previous Work

- Assign captcha challenge to check human behind the request
- Assign resource heavy challenge to client to bring down the client if attempting DoS
- Setup a TIMEOUT (firewall etc. if not on application itself)

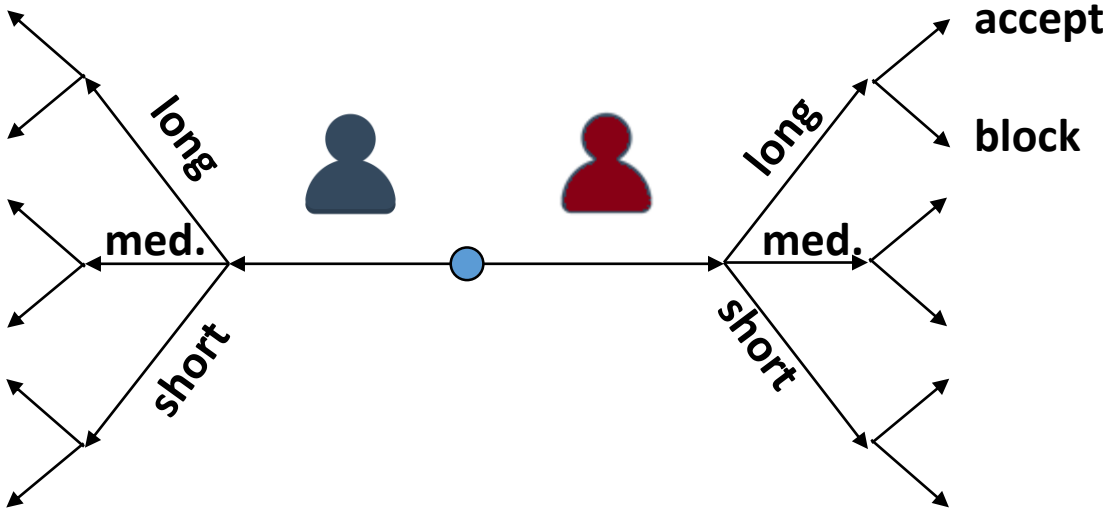
Benign users are affected. Need decision on WHO

Signaling Game

- **Two players w/ conflict of interest**
  - Sender: has types unknown to opponent. Chooses msg to be sent to receiver
  - Receiver: Receives msg from sender and guesses type of sender and chooses action
- **Message**: signal for the receiver to guess the type of sender. Can be a deceit.

In our security game,

- **User**: benign or attacker.
  - Attacker: optimize decision on msg.
  - Benign: no rationality.
- Connection time works as the signal (message)
- **Defender**: monitors connection time and determines response (user type unknown)



Objective

An automated decision model that can protect the system from ‘Hard to Differentiate’ attacks

Real data based game model

Show a practical implementation of a Game Theory based approach for Cyber Security

Preliminary Data Analysis

ts	id.orig_h	id.orig_p	id.resp_h	id.resp_p	duration	orig_bytes	resp_bytes	conn_state	orig
1426395590	141.142.169.3	49662	141.142.2.2	53	0.000224	180	714	SF	US
1426395596	78.186.4.159	35083	141.142.74.100	23	2.976723	0	0	S0	TR
1426395595	107.5.18.180	60253	143.219.110.22	389	-	-	-	S0	US
1426395540	141.142.141.2	44997	149.165.225.1	33447	-	-	-	S0	US

Understanding Benign Traffic

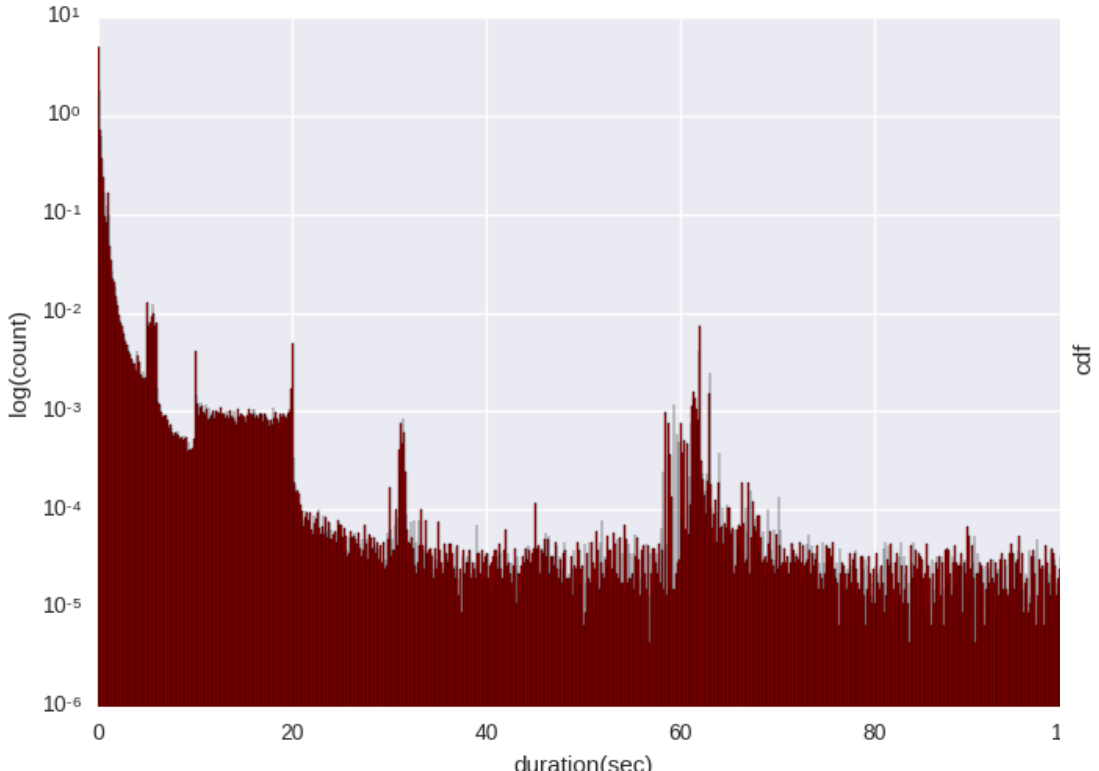
- Web server traffic @NCSA from Jan. 2015 ~ Jun. 2016
  - timestamp, origin / destination (IP and port), protocol, connection duration, connection state, country of origin, size of byte, etc.
- 1M HTTP connections to / from the NCSA website
- No significant sign of NCSA under a slow DoS attack (nothing reported as well)
  - Suspicious Connections: Abnormally long connections with No Bytes actually transferred (0.1%)

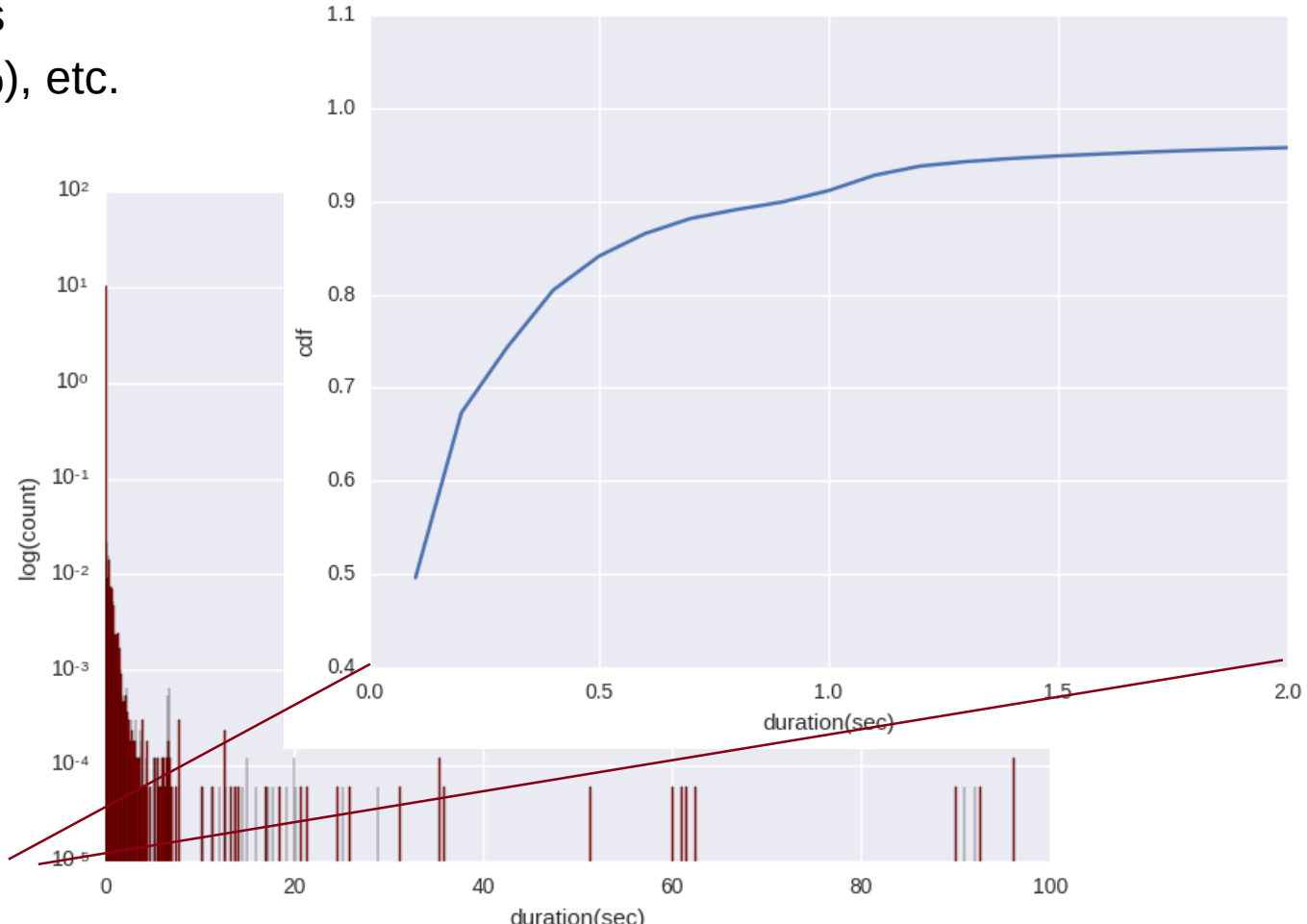
Understanding Attack Traffic

- Run an attack script (slowhttptest) on a victim server
- Monitor the time to failure (of the victim) upon different parameter configurations
- We fix the number of packets (and rate) to assure equivalent visibility

Preliminary Data Analysis

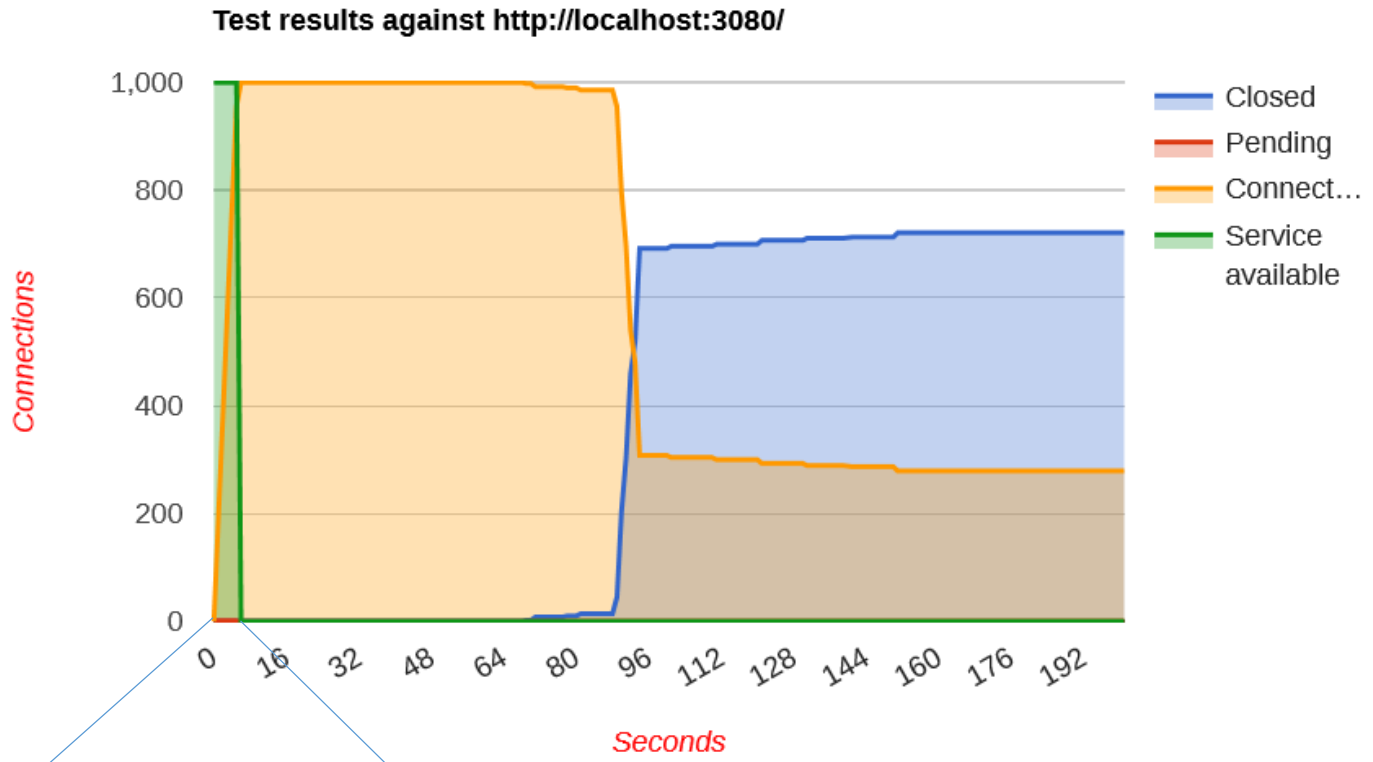
- 212 different originating countries
  - 85% of the traffic is from Top10 countries
  - US (29.81%), GB (27.75%), RU (10.84%), etc.





Preliminary Data Analysis

Test type	SLOW HEADERS
Number of connections	1000
Verb	GET
Content-Length header value	4096
Extra data max length	52
Interval between follow up data	10 seconds
Connections per seconds	200
Timeout for probe connection	3
Target test duration	240 seconds
Using proxy	no proxy

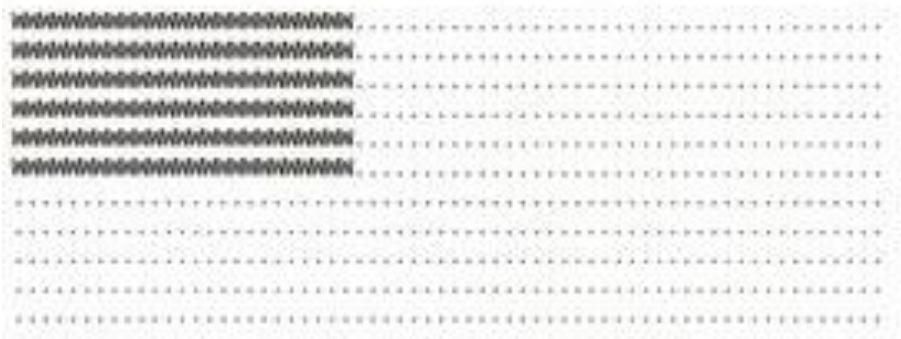


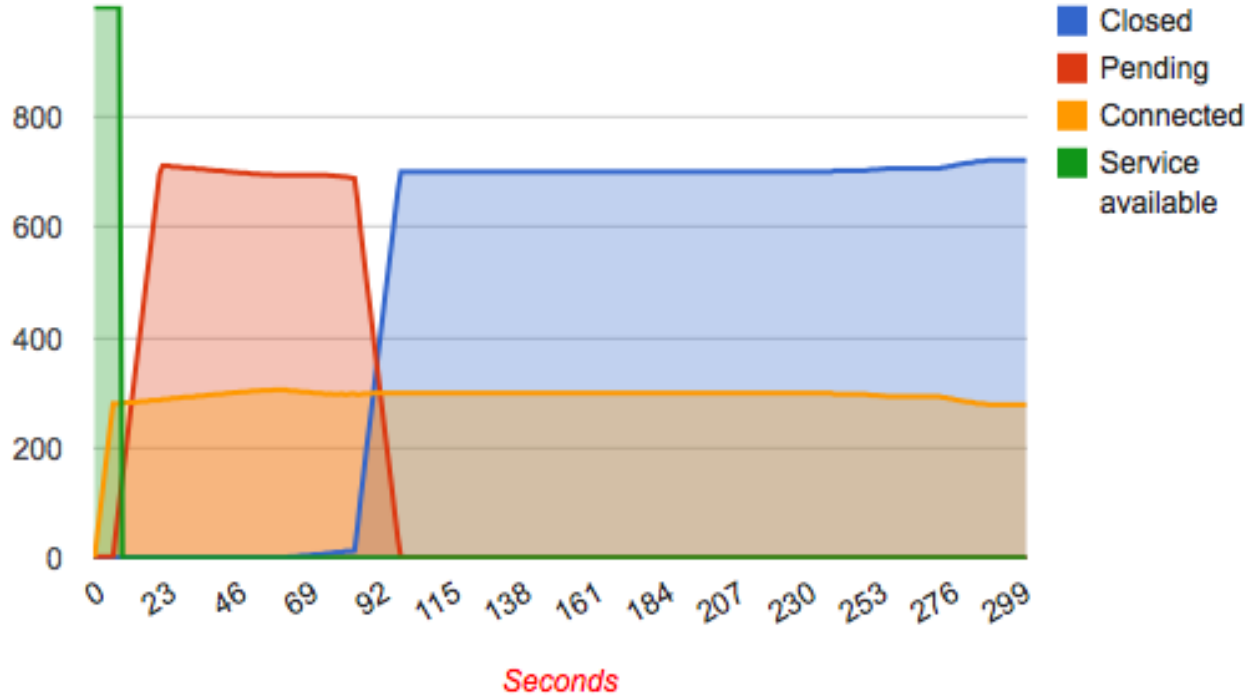
TIME to FAILURE

Preliminary Data Analysis

Test type	SLOW READ
Number of connections	1000
Receive window range	1 - 100
Pipeline factor	10
Read rate from receive buffer	5 bytes / 1 sec
Connections per seconds	50
Timeout for probe connection	5
Target test duration	300 seconds

Server uptime: 1 day 13 hours 29 minutes 54 seconds
Total accesses: 30624 - Total Traffic: 99.2 MB
CPU Usage: u4.12 s.66 cu0 cs0 - .00354% CPU load
.227 requests/sec - 770 B/second - 3396 B/request
150 requests currently being processed, 0 idle workers



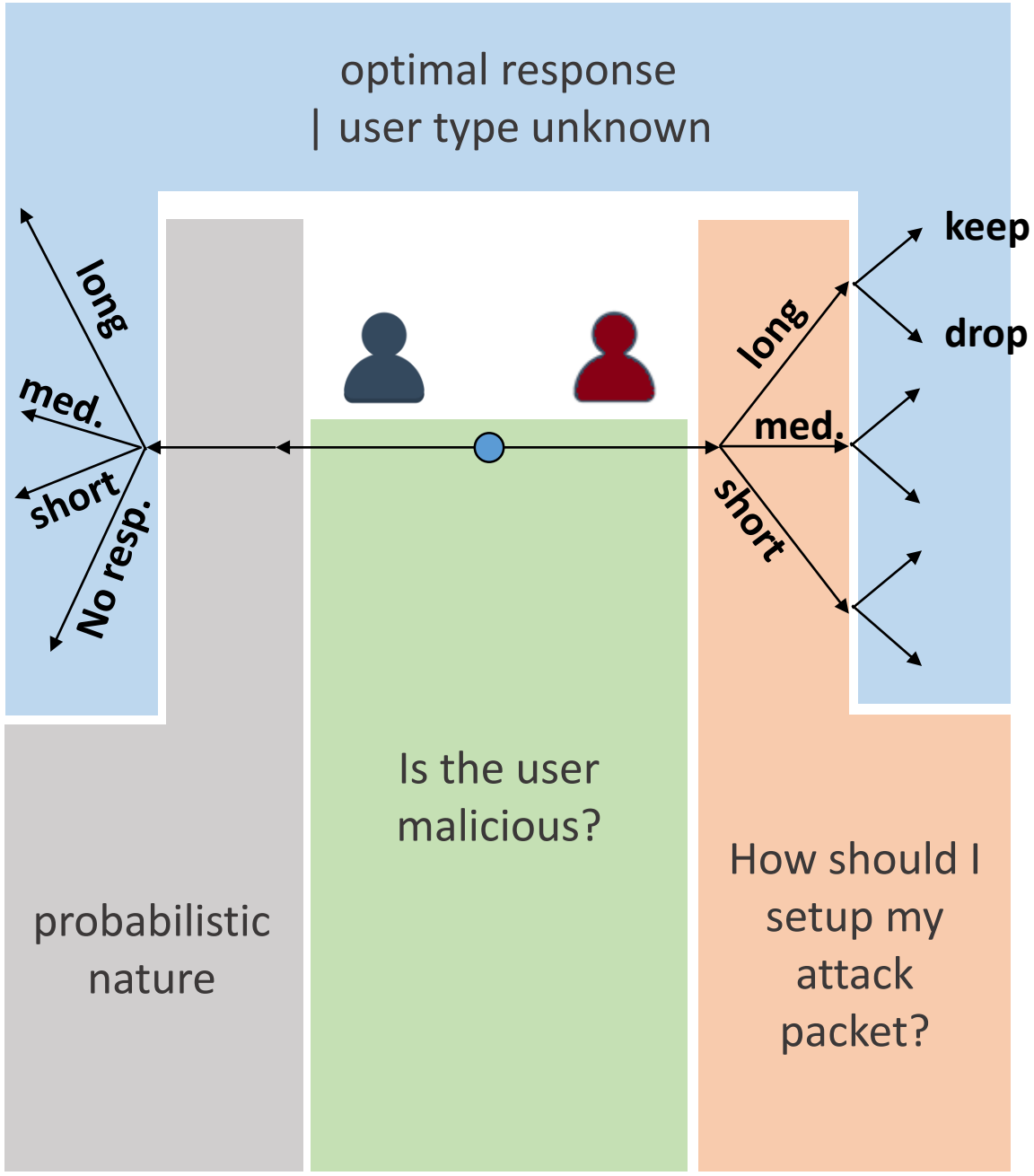


Game Model

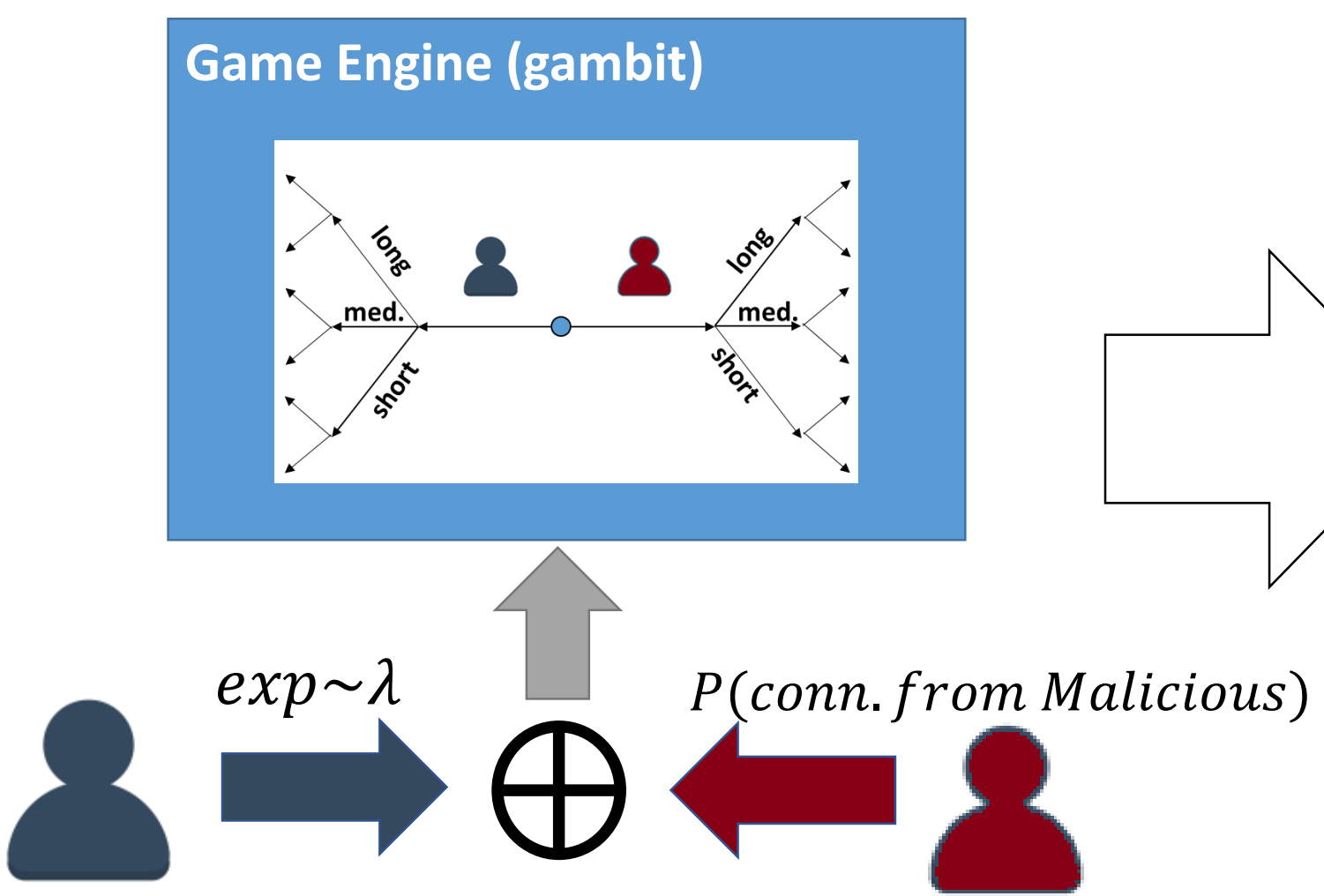
- Uncertainty: **USER TYPE**
- Attacker: optimize connection duration
- Defender: how to handle the packet, given the observation (duration)

- **Reward Model**

	Short	Med Length	Long
TP	±0	±0	±0
FP	± Exp. Users > THR_S	± Exp. Users > THR_M	± Exp. Users > THR_L
TN	±0	±0	±0
FN	± Exp. Users	± Exp. Users	± Exp. Users



Simulation for Accuracy Analysis



Conn #	User	Response
1	Benign	Keep
2	Benign	Keep
3	Benign	Block
4	Benign	Keep
5	Malicious	Block
6	Malicious	Keep
7	Benign	Keep

Simulation Results (1)

- **P(connection from malicious) = 0.01% (suspicious conn. / overall conn)**

Benign (99.99%)		Attacker (0.01%)	
Defender	User	User	Defender
Respond (0.01%)	Long(0.01)	Long(0.05)	Respond (0.01%)
No Respond (99.99%)			No Respond (99.99%)
Respond (0.01%)	Med(0.09)	Med(0.15)	Respond (0.01%)
No Respond (99.99%)			No Respond (99.99%)
Respond (0.01%)	Short(0.9)	Short(0.8)	Respond (0.01%)
No Respond (99.99%)			No Respond (99.99%)

- **High False Negative Rate (most packets are missed)**
- Attacker prefers a short connection (High impact for false positives)
- **No optimal value for P(connection from malicious)**

Simulation Results (2)

- **P(connection from malicious) = 50%**

Benign (50%)		Attacker (50%)	
Defender	User	User	Defender
Respond (33.98%)	Long(0.01)	Long(0.00)	Respond (33.98%)
No Respond (66.02%)			No Respond (66.02%)
Respond (41.77%)	Med(0.09)	Med(0.03)	Respond (41.77%)
No Respond (58.23%)			No Respond (58.23%)
Respond (57.25%)	Short(0.9)	Short(0.97)	Respond (57.25%)
No Respond (43.75%)			No Respond (43.75%)

- **Issues remain for accuracy**
- No optimal value for P(connection from malicious)

Discussion & Future Work

- **P(connection from malicious) has significant impact on the game analysis**
  - **Unknown to the defender from monitoring**
  - **Sensitivity testing for different P values**
  - **Need for a preliminary analysis to derive the optimal P:**
    results from a ML based detector can be a possibility

- **Accuracy of the reward model**
  - **Unlike Q-Learning model, the reward model needs to properly represent the interaction**
  - **Need for a verification on the reward model:**
    factor the impact of difficulty of detection into reward model

- Test on timeliness and accuracy on a real system

Implementation in a Real System

- Q. Is the decision made in a timely manner?
- Q. How accurate is the detection?