

# Gametheory and Cybersecurity: a study Fliplt and multiple resources

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Thesis voorgedragen tot het behalen  
van de graad van Master of Science  
in de ingenieurswetenschappen:  
computerwetenschappen,  
hoofdspecialisatie Veilige software

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Voorafgaande schriftelijke toestemming van de promotor is eveneens vereist voor het aanwenden van de in deze masterproef beschreven (originele) methoden, producten, schakelingen en programma's voor industrieel of commercieel nut en voor de inzending van deze publicatie ter deelname aan wetenschappelijke prijzen of wedstrijden.

# Voorwoord

I would like to thank everybody who kept me busy the last year, especially my promotor and my assistants. I would also like to thank the jury for reading the text. My sincere gratitude also goes to my wife and the rest of my family.

*Sophie Marien*

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# Samenvatting

In this thesis I present a work of gametheory merged with cybersecurity. The **abstract** environment contains a more extensive overview of the work. But it should be limited to one page.

# Samenvatting

In dit **abstract** environment wordt een al dan niet uitgebreide Nederlandse samenvatting van het werk gegeven. Wanneer de tekst voor een Nederlandstalige master in het Engels wordt geschreven, wordt hier normaal een uitgebreide samenvatting verwacht, bijvoorbeeld een tiental bladzijden.

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# List of Abbreviations and Symbols

## Abbreviations

LoG	Laplacian-of-Gaussian
MSE	Mean Square error
PSNR	Peak Signal-to-Noise ratio

## Symbols

42	“The Answer to the Ultimate Question of Life, the Universe, and Everything” according to <a href="#">[1]</a>
$c$	Speed of light
$E$	Energy
$m$	Mass
$\pi$	The number pi



# Hoofdstuk 1

## Introduction

The first contains a general introduction to the work. The goals are defined and the modus operandi is explained.

### 1.1 chap



## Hoofdstuk 2

# Introduction to Game Theory

In the following paragraph an introduction to game theory is given based on the work of [?] and [?]. For a more detailed and full introduction to game theory, the reader is referred to [?].

### 2.1 Intro Game Theory

Game theory studies the interaction between independent and self-interested agents. It is a mathematical way of modelling the interactions between two or more agents where the outcomes depend on what everybody does and how it should be structured to lead to good outcomes. For this reason it is very important for economics and also for politics, biology, computer science, philosophy and a variety of other disciplines.

One of the assumptions underlying game theory is that the players of the game, the agents, are independent and self-interested. This does not necessarily mean that they want to harm other agents or that they only care about themselves. Instead it means that each agent has preferences about the states of the world he likes. These preferences are mapped to natural numbers and are called the utility function. The numbers are interpreted as a mathematical measure to tell you how much an agent likes or dislikes the states of the world.

It also explains the impact of uncertainty. When an agent is uncertain about a distribution of outcomes, his utility will describe the expected value of the utility function with respect to the probability of the distribution of the outcomes. For example: with 0.7 probability it will be 7 degrees outside and 0.3 probability it will be 10 degrees. The agent can have a different opinion about that distribution versus another distribution. ().

In a decision game theoretic approach an agent will try to act in such a way to maximise his expected or average utility function. It becomes more complicated when two or more agents want to maximise their utility and whose actions can affect each other utilities. This kind of games are referred to as non cooperative game theory, where the basic modelling unit is the group of agents. The individualistic approach, where the basic modelling is only one agent, is referred as cooperative

uitleggen aan  
de hand van een  
voorbeeld

game theory.

There are two standard representations for games. The first one is the Normal Form. The second one is the Extensive Form.

In the following list a couple of terms that will be used throughout the paper.

*Players:* players are referred as the ones who are the decision makers. It can be a person, a company or an animal.

*Actions:* actions are what the player can do.

*Outcomes:*

*Utility function:* the utility function is the mapping of the level of happiness of an agent about the state of the world to natural numbers.

*Strategies:* A strategy is the combination of different actions. A pure strategy is only one action.

A game in game theory consists of multiple agents and every agent has a set of actions that he can play.

## 2.2 Virusses

Ways of defending a network:

- Self-defending networks: The next generation of network security
- Honeynet games: a game theoretic approach to defending network monitors

Many network security threats today are spread over the Internet. The most common include:

Viruses, worms, and Trojan horses Spyware and adware Zero-day attacks, also called zero-hour attacks Hacker attacks Denial of service attacks Data interception and theft Identity theft

Computer virus through mail. Though virus spreading through email is an old technique, it is still effective and is widely used by current viruses and worms. Sending viruses through email has some advantages that are attractive to virus writers: Sending viruses through email does not require any security holes in computer operating systems or software. Almost everyone who uses computers uses email service. A large number of users have little knowledge of email viruses and trust most email they receive, especially email from their friends [28][29]. Email are private properties like post office letters. Thus correspondent laws or policies are required to permit checking email content for detecting viruses before end users receive email [18].

Send a email with malicious attachment. Only again infected if attachment again opened. Thus this is the action of attacking every neighbour node + also can attack again the node where the virus was coming from. There are also email viruses were the malicious program is hidden in the txt and the attachment does not need to be opened.

### 2.2.1 Malware

Relevant researches:

- How Viruses and worm can be detected. Difference between UDP en TCP worm propagation

## 2.3 Conclusion

The final section of the chapter gives an overview of the important results of this chapter. This implies that the introductory chapter and the concluding chapter don't need a conclusion.





# Hoofdstuk 3

## The FlipIt game

### 3.1 Extensions on FlipIt

There are various possible ways to extend FlipIt. For instance Laszka et al. extended the basic FlipIt game to multiple resources. The incentive is that for compromising a system in a real case it needs more than just taking over one resource. An example is gaining access to a system and breaking the password. The model is called FlipThem [2]. Two ways of flipping the resources are used: the AND and the OR control model. In the AND model the attacker only controls the system if he controls all the resources of the system, whereas in the OR model the attacker only needs to compromise one resource to be in control of the entire system. The difference with FlipThem and this paper is that we introduce a Graph Model in the beginning. Another extension on FlipIt is done by Pham [1]. Beside the action Flip there is another action Test. The basic idea is to test with an extra action if the resource has been compromised or not. This action involves also an extra cost. This model is useful if somebody wants to know for example if his password has been compromised or wants to assess the periodic security of a system. In [?] [?] Laszka et al. they also consider non targeted attacks by non-strategic players and .

citatie needed  
voor Are We  
Compromised?

verder aanvul-  
len

In this section, we introduce the game FlipIt [4]. FlipIt is a game introduced by .. and Rivest. First we explain the framework of FlipIt and after that the formulas and assumptions that we will make for the game for during the whole paper.

### 3.2 The First Topic of this Chapter

FlipIt is a two-players game with a shared (single) resource that the players want to control as long as possible. The shared resource can be a password, a network or a secret key depending on the setting being modelled. In the rest of the paper we will call the players the Attacker and the Defender. To get the control over the resource, players can flip the resource at any given time. Each move will imply a certain cost. The unique feature of FlipIt is that the move will happen in a stealthy way, meaning that the other player has no clue that the other player has flipped the resource. For instance, the defender will not find out if the resource has already been

compromised by the attacker, but he can only potentially know it after he flips the resource himself. The goal of the player is to maximize the time that he or she has control over the resource while minimizing total cost of the moves. Players won't move to frequently. A move can also result in a "wasted move", called a flop. It may happen that the resource was already under control by the defender. If the defender moves when he or she has already control over the resource, he or she would have wasted move since it does not result in a change of ownership.

Because the players move in a stealthy way, there are different types of feedback that a player can get while moving:

- Non-adaptive (NA): The player does not receive any feedback while flipping.
- Last move (LM): The player finds out the exact time the opponent played the last time.
- Full History (FH): The player finds out the complete history of the opponents move.

The game can be extended by the amount of information that a player receives. It can also be possible for a player to get information at the start of the game. Both interesting cases are:

- Rate-of-play (RP): The player finds out the exact rate of play of the opponent.
- Knowledge-of-strategy (KS): The player finds out the complete information of the strategy that the opponent is playing.

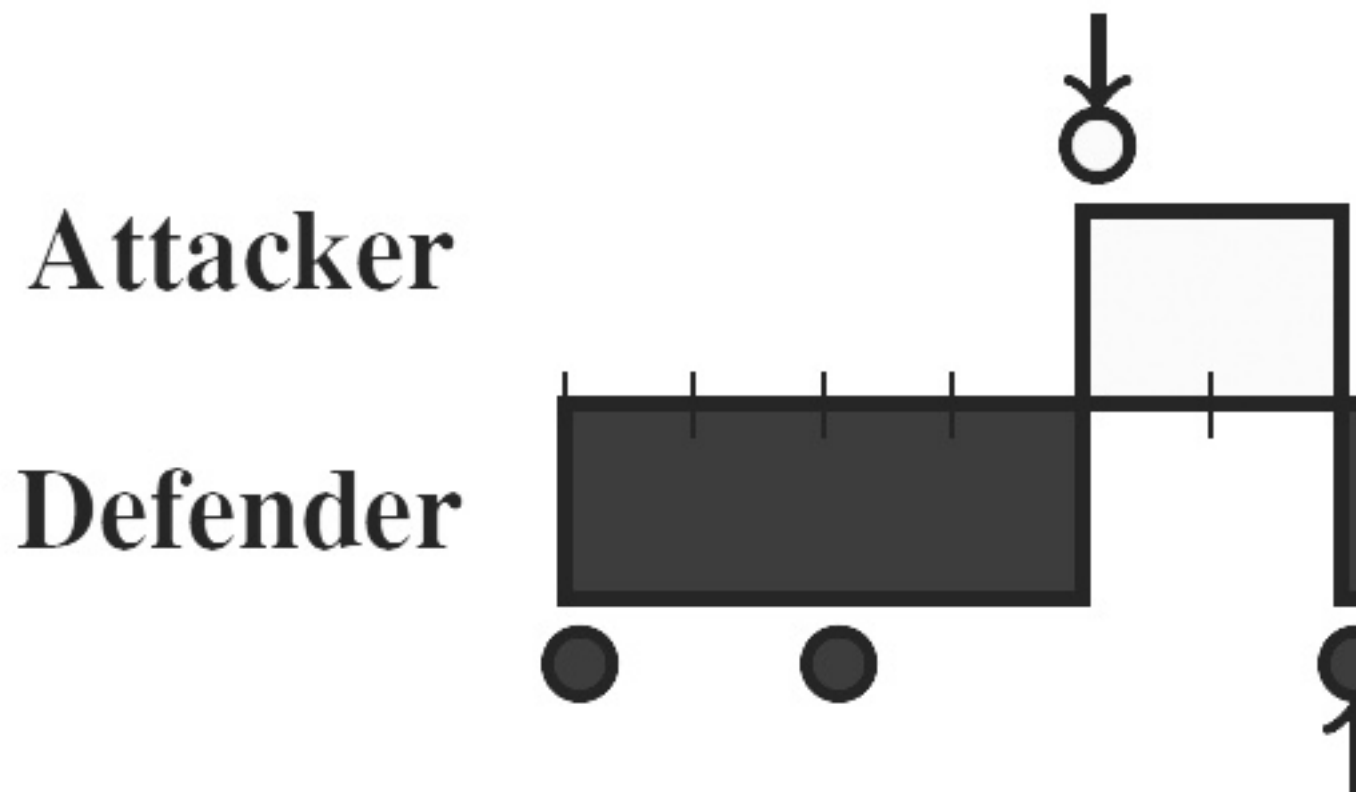
In our assumption the strategy of both players will be non-adaptive. None of the players has information of the strategy of the opponent.

### 3.3 Figures

verwijzen naar  
de figuur 3.1

### 3.4 Conclusion

The final section of the chapter gives an overview of the important results of this chapter. This implies that the introductory chapter and the concluding chapter don't need a conclusion.



FIGUUR 3.1: The FlipIt game where both players are playing periodically

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natbib pgf tikz  
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lipsum

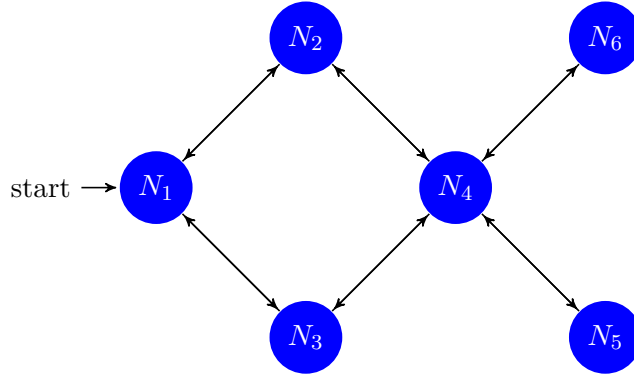
### 3.5 Write down the settings of the game

source: [http://en.wikipedia.org/wiki/Adjacency\\_matrix](http://en.wikipedia.org/wiki/Adjacency_matrix)

We model the network through an undirected Graph  $G = \langle V, E \rangle$  where  $|V|$  denotes the number of resources in the network and  $|E|$  the number of connections. We can convert this to a adjacent matrix where we can represent which vertices of the graph are neighbours of other vertices.

For our graph we have an  $|V| \times |V|$  matrix with on every entry  $a_{ij}$  a 1 as value if there is a connection between node  $V_i$  and  $V_j$  and with zeros its diagonal. Because our graph is undirected we have a symmetric matrix.

*"If  $A$  is the adjacency matrix of the directed or undirected graph  $G$ , then the matrix  $A^n$  (i.e., the matrix product of  $n$  copies of  $A$ ) has an interesting interpretation: the entry in row  $i$  and column  $j$  gives the number of (directed or undirected) walks of length  $n$  from vertex  $i$  to vertex  $j$ . If  $n$  is the smallest nonnegative integer, such that for all  $i, j$ , the  $(i, j)$ -entry of  $A^n > 0$ , then  $n$  is the distance between vertex  $i$  and vertex  $j$ ." [Wikipedia]*



The adjacent matrix becomes this matrix  $[A]$ :

$$\begin{matrix} & N_1 & N_2 & N_3 & N_4 & N_5 & N_6 \\ \begin{matrix} N_1 \\ N_2 \\ N_3 \\ N_4 \\ N_5 \\ N_6 \end{matrix} & \begin{pmatrix} 0 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix} \end{matrix}$$

Matrix  $A \times A = A^2$  becomes the matrix with the number of paths with 2 steps from  $N_i$  to  $N_j$ : We denote this matrix as matrix  $[B]$

$$\begin{array}{c}
 N_1 \quad N_2 \quad N_3 \quad N_4 \quad N_5 \quad N_6 \\
 \begin{array}{c} N_1 \\ N_2 \\ N_3 \\ N_4 \\ N_5 \\ N_6 \end{array} \begin{pmatrix} 2 & 0 & 0 & 2 & 0 & 0 \\ 0 & 2 & 2 & 0 & 1 & 1 \\ 0 & 2 & 2 & 0 & 1 & 1 \\ 2 & 0 & 0 & 4 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 1 & 1 \end{pmatrix}
 \end{array}$$

Matrix  $A^2 \times A = A^3$  becomes the matrix with the number of paths with 3 steps from  $N_i$  to  $N_j$ : We denote this matrix as matrix  $[C]$

$$\begin{array}{c}
 N_1 \quad N_2 \quad N_3 \quad N_4 \quad N_5 \quad N_6 \\
 \begin{array}{c} N_1 \\ N_2 \\ N_3 \\ N_4 \\ N_5 \\ N_6 \end{array} \begin{pmatrix} 0 & 4 & 4 & 0 & 2 & 2 \\ 4 & 0 & 0 & 6 & 0 & 0 \\ 4 & 0 & 0 & 6 & 0 & 0 \\ 0 & 6 & 6 & 0 & 4 & 4 \\ 2 & 0 & 0 & 4 & 0 & 0 \\ 2 & 0 & 0 & 4 & 0 & 0 \end{pmatrix}
 \end{array}$$

So for  $A^N$  every  $a_{ij}$  entry gives the number of paths with N steps from  $N_i$  to  $N_j$ .

With this knowledge we can calculate in how many steps a node is infected.  $A$  calculates which nodes are infected after 1 step,  $A^N$  calculates which nodes are infected in N steps.. So if we want to know how many nodes are infected after 3 steps we have to add every matrix ( $A + A^2 + A^3$ ) and see which entry is a non zero entry.

What do we need for an algorithm

Graph network  $G = \langle V, E \rangle$

Graph matrix  $[A]$  which is  $|V| \times |V|$

Attack vector  $[X]$  which is  $1 \times |V|$

cummulative matrix  $[M]$  which is  $|V| \times |V|$

state matrix  $[T]$  which is  $|V| \times |V|$

Reset vector  $[R]$

duration  $d$

time  $n$

rate  $\delta_0$  of defender and  $\delta_1$  of attacker

Initialisation algorithm:

### 3. THE FLIPIT GAME

---

```
initialisatie
d=0
A=basismatrix
M=A{0}
n=0
\delta_{0}
\delta_{1}
X
R
controller = defender
```

```
Algorithm
n:= n + 1;
Check who is in control? ( through modulo )
if ( defender & controller=defender)
d:= d + 1;

if ( defender & controller=attacker )
G = X \times R (flippen ten voordele van defender)
d = 0
controller = defender

if ( attacker & controller=defender )
controller=attacker
..

if ( attacker & controller=attacker )
d:= d + 1
M = M x A
T = T + M
G = X x T
```

## Fiche masterproef

*Student:* Sophie Marien

*Titel:* Gametheory and Cybersecurity: a study FlipIt and multiple resources

*Engelse titel:* Beste masterproef ooit al geschreven

*UDC:* 621.3

*Korte inhoud:*

Hier komt een heel bondig abstract van hooguit 500 woorden.  $\text{\LaTeX}$  commando's mogen hier gebruikt worden. Blanco lijnen (of het commando `\par`) zijn wel niet toegelaten!

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Thesis voorgedragen tot het behalen van de graad van Master of Science in de ingenieurswetenschappen: computerwetenschappen, hoofdspecialisatie Veilige software

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