Artificial Immune System
inspired by Human Immune System

Bait a Trap: Introducing Natural Killer Cells to Artificial Immune System for Spyware Detection

Complex Adaptive Systems Seminar
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Outline

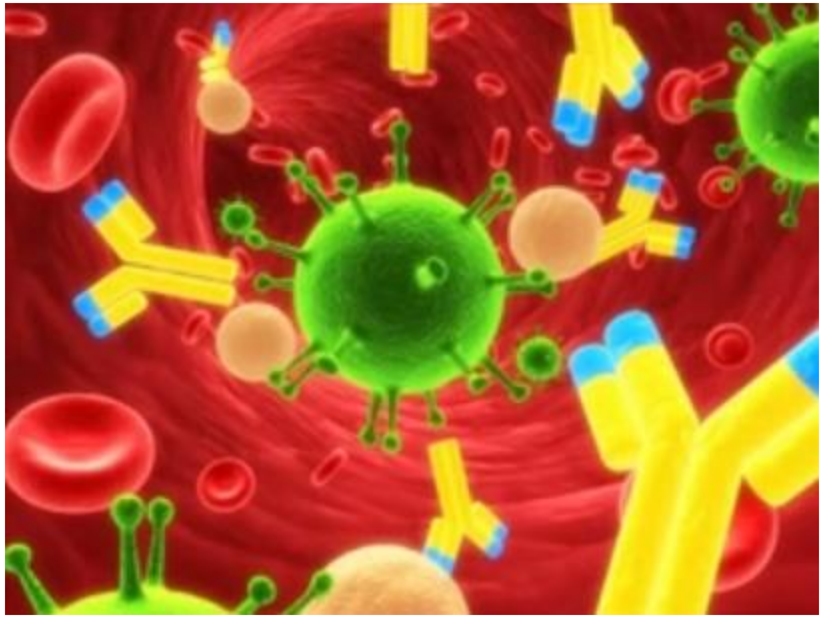
- Human immune system
- Artificial immune system
- What is Spyware
- Proposed mechanism
- Results
- Future of AIS

Human Immune System

- Its goal
  - Protect our body against foreign invaders and infectious
- Important players
  - Lymphocytes (B-Cells, T-Cells, Natural Killers (NK))
- How it works (work steps)
  - Recognize
  - Attack
  - Memorize
- Why it is important to investigate
  - Powerful information processing capabilities
  - Highly parallel system
  - Use learning, memory and retrieval to solve recognition and classification

How HIS works

- Try to recognize all of the body cells
  - Classified them as self and non-self
    - Non-self are further categorized by type of defensive mechanism



How HIS works

- Encountering antigens use two different approaches:
  - Innate mechanism
    - Non-specific response (defense)
  - Adaptive(acquire) mechanism
    - Specific response by applying hyper mutations of different genes
      - Clonal expansion
- After successful defense
  - Memorizing the antigens and the location they are exposed

Artificial Immune System(AIS)

- Inspired metaphors from HIS
  - Recognition (Self vs Non-self)
  - Feature extraction (by filtering released proteins - cytokine)
  - Diversity (by hyper mutation of different genes)
  - Learning
  - Memory
  - Decentralize controlling (vs nervous system)

Artificial Immune System(AIS)

- Applications

  - Machine learning (e.g. Pattern recognition, Data clustering)
  - Computer security - Malware detection (Virus, Spyware, …)
  - Fault diagnosis and tolerance
  - Robotics
  - Optimization
  - Scheduling

<u>Spyware</u> (and current popular detection approaches)

- Spyware is designed to make money by stealing users’ privacy or confidential data, rather than harm the computer systems or self-reproduce in the network
  - Hiding their presence (hide its files and registries)
  - Hiding their behaviors (pretend their behaviors are legitimate)

- Regular detection approaches
  - Signature-based
    - Detect known spywares with high degree of accuracy
    - Unable to detect novel ones
  - Behavior-based
    - Can detect partial new spyware with acceptable accuracy

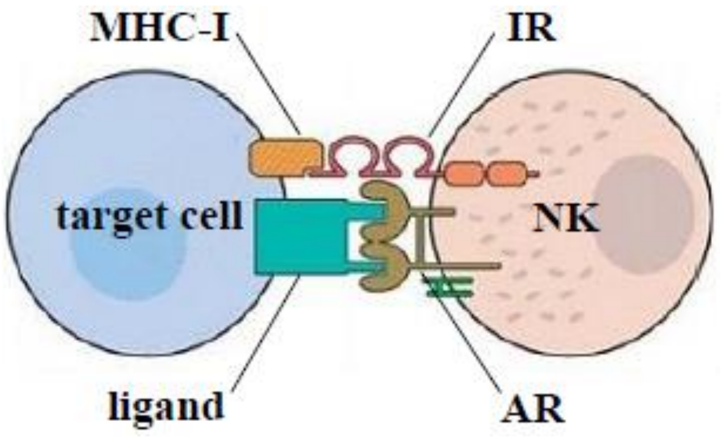
Natural Killers (NKs)

- Powerful weapons to find and kill the latent viruses (Viruses which decreased their activity to escape the attacks performed by HIS)
- They provide some baits to encourage latent viruses to exhibit their activities more obvious (-> can be recognize by immune cells)
- NKs mechanism is introduced by the authors of the article to facilitate the latent spyware detection process

Natural Killers (NKs)

- Mechanisms
  - Have different surface receptors
    - These receptors regulate the cell functions by signal transduction

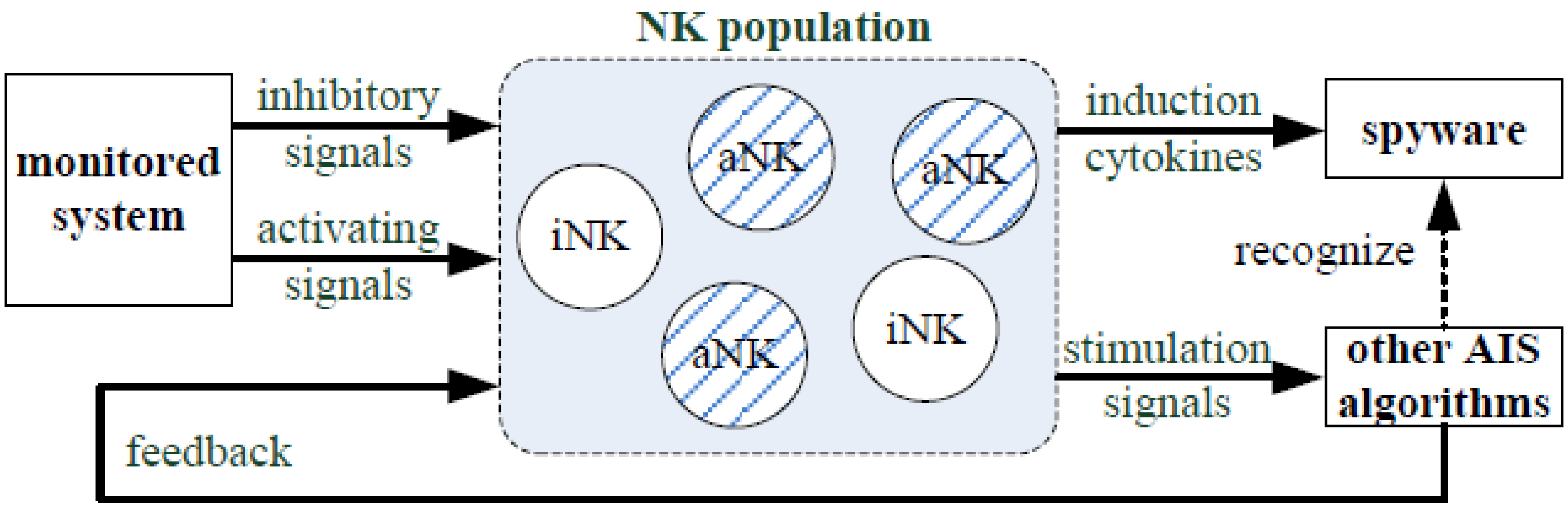
    - Taxonomy of receptors
      - Inhibitory receptors (IRs)
      - Activating receptors (ARs)



Natural Killers (NKs)

- How NKs decide to kill or leave the binding cell
  - Based on the balance between inhibitory and activating signals
  - If the summation of these signals is negative
    - The cell is left and categorized as a normal cell
  - Otherwise
    - The cell is killed since it is recognized as an infection
      - NK produce proteins (e.g. perforins) to split the target cell cause to expose the virus

Artificial NK model



- Artificial inhibitory signals ⇦ from processes, files, and registries
- Artificial activating signals ⇦ from key logging, information collecting and leaking
- Artificial induction cytokine ⇨ generating artificial user activities in computer systems

Artificial cell representation

- Artificial Natural Killer (NK)
  - NK(NKRs, Fitness, AV, Status, IC)
    - NKRs: Natural Killer Receptors (Inhibitory receptor - IR / Activating receptor - AR)
    - Fitness: Cell adaptability is measured by its fitness (higher fitness -> more adaptable)
    - AV: Activating value (cumulative value increasing by AR signals and decreasing by IR signals)
    - Status: which initially is inactive. If exceeds a threshold, the NK status changes to active
    - IC: each NK can produce a specific type of IC. Since each spyware exhibit different behavior

Artificial cell representation

- Artificial Natural Killer Receptor (NKR)
  - NKR(Type, Ligand, Affinity, Weight)
    - Type: Shows if it is IR or AR
    - Ligand: Shows which source is bound to the receptor (e.g. file and registry expressions of a program)
    - Affinity: determines the value of the perceived signals
    - Weight: for IR, Weight < 0 and for AR, Weight > 0

Recognition and response algorithm

- **forall the** *signals* **do**
  - **forall the** *NKs* **do**
    - set the affinity of all NKRs to 0;
    - get signal *s*;
    - find all NKRs (*mNKRs*) that match *s*;
    - **forall the** *mNKRs* **do**
      - *mNKR.affinity = s.value*;
    - **end**
    - calculate the *AV* of the NK;
    - **if** *AV* ≥ *TA (activating threshold) and NK.status == inactive* **then**
      - *NK.status = active*;
    - **end**
  - **end**
- **end**
- Input: Signals (both inhibitory and activating)
- Output: The status of NK (active or inactive)

Recognition and response algorithm

- The AV is computed by:

  - $AV_{after} = AV_{before} + \sum_{mNKRs} Affinity * Weight$

- Once NK activated, generates artificial user activities by IC
  - If spyware does not detect it as a fake activity
    - responds to it

Recognition and response algorithm

- Artificial induction cytokine (IC)
  - Is defined as a series of bogus user activities
  - $IC = \{UA_1, UA_2, \dots, UA_n\}$

Recognition and response algorithm

- Artificial IC properties
  - $IC(K_{UA}, R, C_0, T_I, T_N, f)$

K_{UA}: kind of IC (e.g. keystroke, file operation, network request)

R: Cycle number (shows induction and non-induction period)

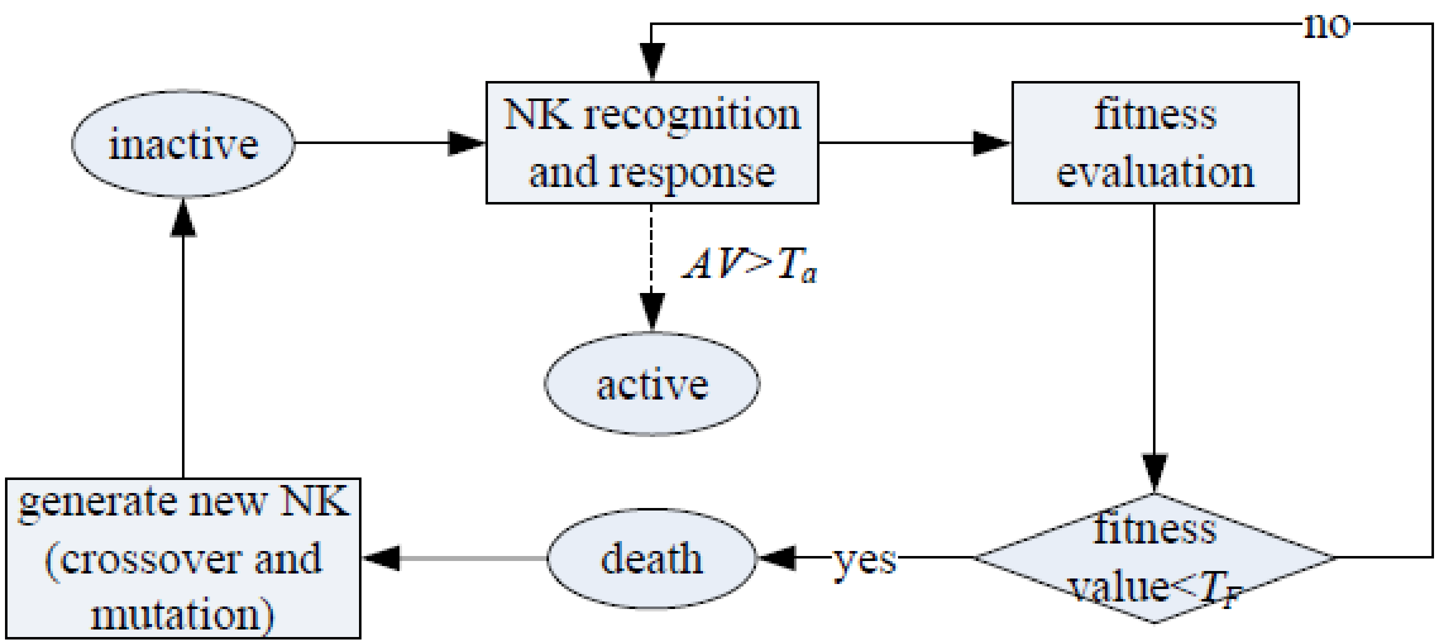
C_0: initial concentration of IC in the beginning of each cycle

T_I: time span of each induction period

T_N: time span of each non-induction period

f: function of the IC concentration and time in induction period

Evolution process (NK lifecycle)



- Fitness is computed by:
  - $Fitness_{after} = Fitness_{before} * (1 - C_{decay}) + \sum_{mNKRs} Affinity * |Weight|$
  - C_{decay}: attenuation coefficient ($0 < C_{decay} < 1$)

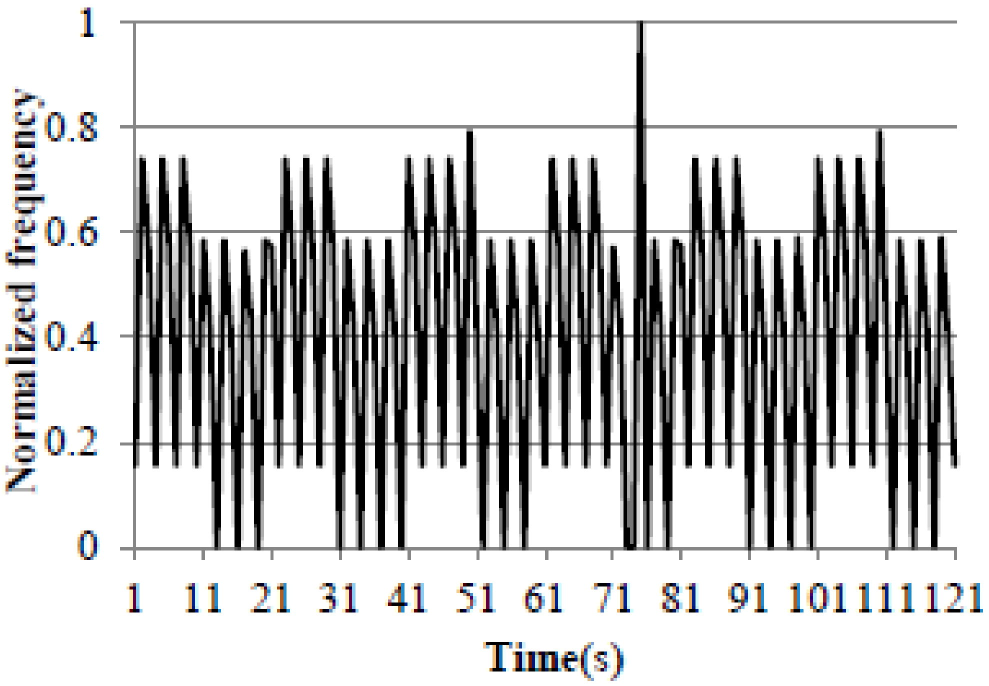
Experiments with real spywares

Functions/Features	Actual Spy V3.0	Spybot V1.2
Keystroke logging		√
File operation logging	√	
Internet traces logging	√	
Send logging report	√	√
Hiding appearance	√	
Hiding behavior		√

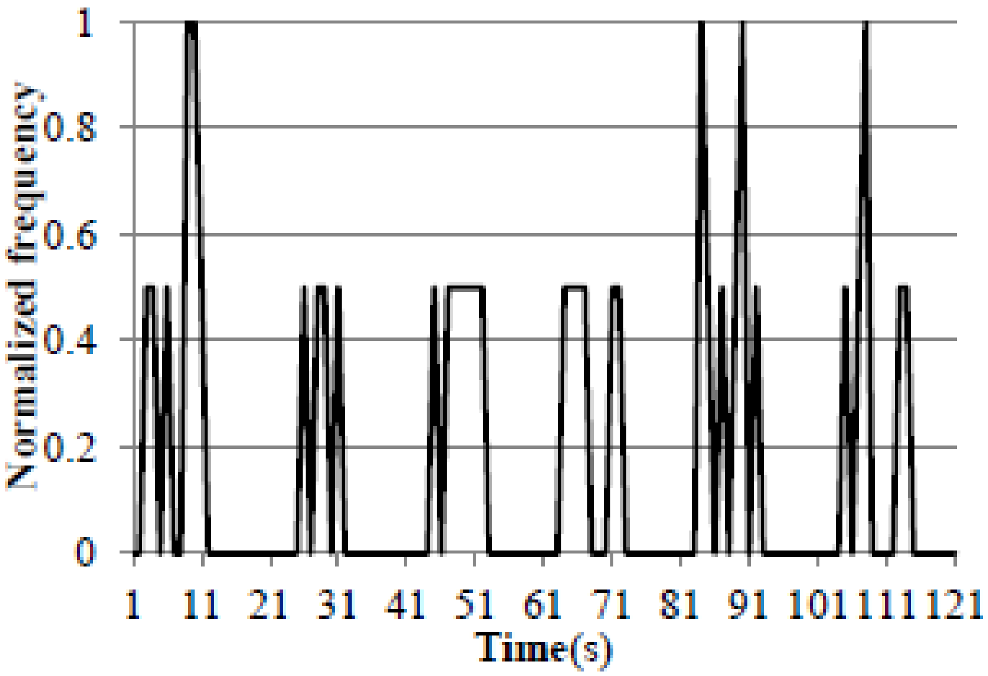
Four different ICs are introduced

- $IC_{keystroke}$: Simulate user keystroke
- $IC_{FileOper}$: Simulate the creation, deletion of files
- $IC_{WebSurf}$: Simulate opening web pages in a browser
- $IC_{HTTPReq}$: Generate HTTP requests

Experiment's results

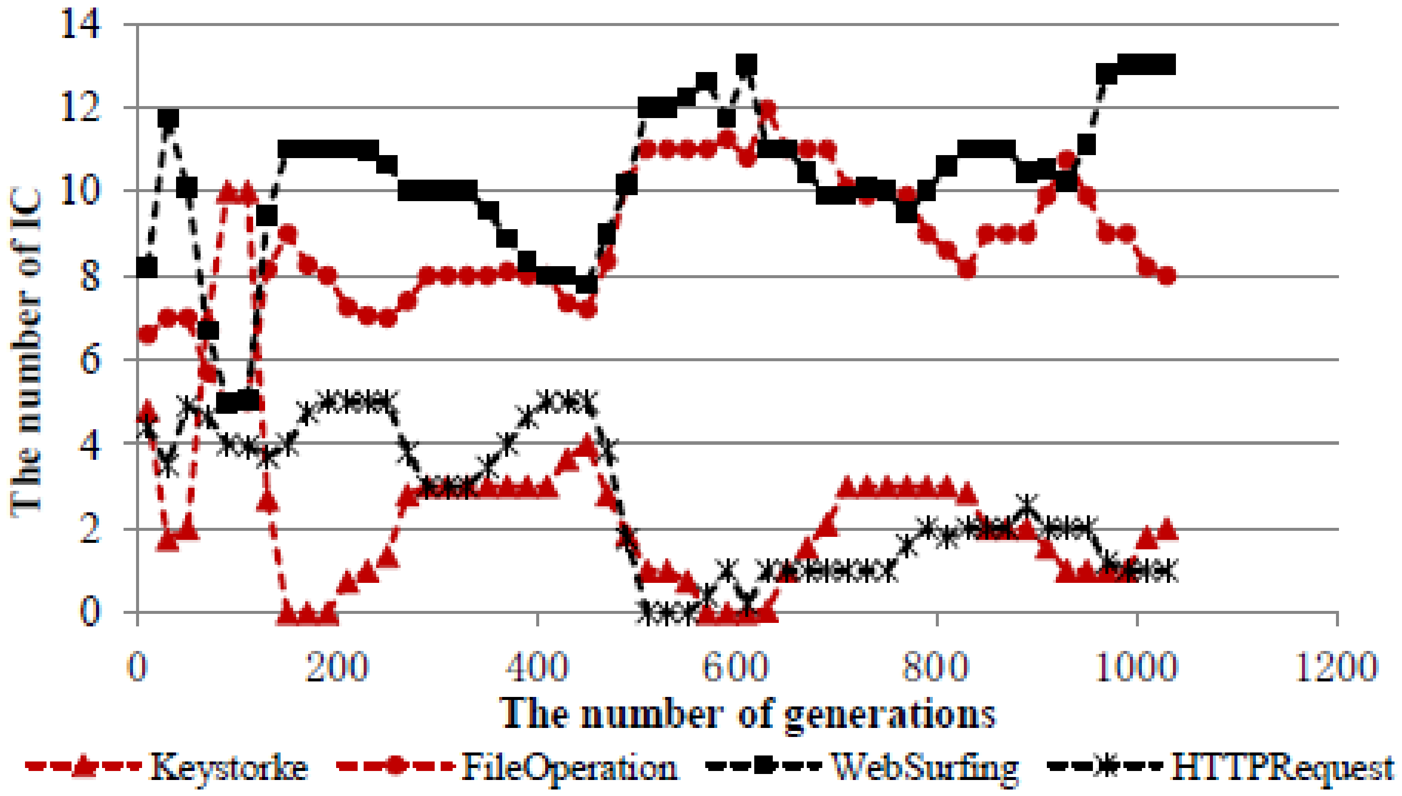


(a) Actual Spy ($IC_{FileOper}$)



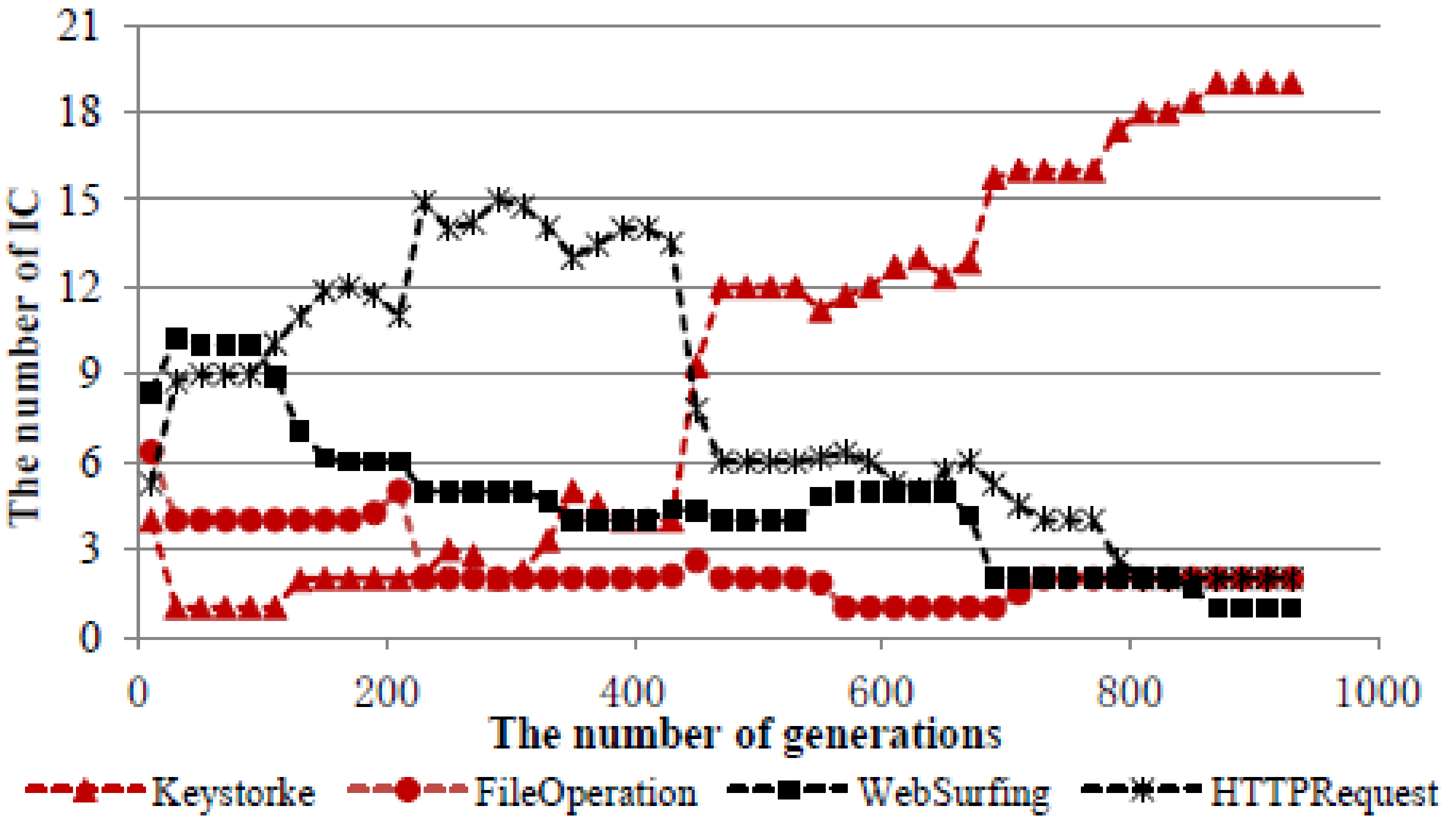
(b) Spybot ($IC_{Keystroke}$)

Experiment’s results



The changes in number of all kinds of ICs in S1 (Actual Spy)

Experiment's results



The changes in number of all kinds of ICs in S2 (Spybot)


Thank You