Gyrus: A Framework for User-Intent Monitoring of Text-Based Networked Applications

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Traditional Host-Based Security

• Misuse detection: cannot handle unknown attacks
• Anomaly detection: mimicry attacks
Motivation

• Defining attack is hard
  – 0-day, mimicry attack, and etc...
  – Attacks are keep evolving...

• Then, can we design a security monitor that works for the new attacks?
A New Approach

• Objective
  – Protecting *integrity* of user intended *text content* that will be sent as *network packets*.

• Attack-agnostic Defense
  – It does *not* depend on the *how* the attack works.
    • Examples of the ways of attacks
      – Attach to a process to change some text values...
      – Directly write on `/dev/mem` to modify sensitive values...
  – We only make sure the monitored system is behaving *correctly*
    • Essentially looking at the opposite side of attack detection.
Related Works

• Using Timing Information
  – BINDER [ACSAC 05’, Cui et. al.]
  – Not-A-Bot, [NSDI 09’, Gummadi et. al.]
  – User-intent Detection
    • Monitors physical keystrokes/mouse clicks
    • A traffic without user input preceded in a short time window is not user-intended, a malicious activity.
      – User-intended behavior: $T_{\text{network}} - T_{\text{input}} < T_{\text{threshold}}$
    – Simple, but effective defense for existing attacks
Related Works (Cont’d)

• User-Driven Access Control [Oakland 12’, Roesner et. al.]
  – Access Control Gadget (ACG)
    • A UI gadget that grants permission to the resource when it is clicked.
      – Examples
        » Camera icon -> grant access to camera
        » File-saving icon -> grant access to filesystem
Related Works (Cont’d)

• **Problem**
  – Only checks existence of user intent (yes/no)
  – BINDER & Not-A-Bot
    • Send malicious network traffic shortly after *every keystrokes*
  – ACG
    • Free to use the resource after getting of the access
  – Nobody took account into monitoring user-intended content.
    • Why?
Capturing User-intended Text

• Straightforward way
  – Looking at keystrokes
    • Keycode can be caught at keyboard driver
    • Cursor point and button can be caught at mouse driver
      – (x, y, button) -> (325, 641, LCLICK)
Capturing User-intended Text

• Challenges
  – Mouse
    • Move cursor on click!
    • Drag to select text, then delete
  – Keyboard
    • Copy & Paste
    • AutoComplete
  – Rich semantics of UI is needed.
Capturing User-intended Text

• A better approach
  – User interacts with computer using input/output hardware
    • Input: Keyboard, Mouse
    • Output: Display screen
  – Feedback loop in the user interaction
Capturing User-intended Text

• Observation
  – User naturally verifies what they type by what they sees on the screen

• A New Security Policy
  – What You See Is What You Send (WYSIWYS)
    • We assume on-screen text is user-intended
    • Only allows outgoing traffic that matches on-screen text
Secure Overlay

On-screen text is always same with captured text on the security monitor.
Secure Overlay

• Only re-draws editbox
  – Exactly same location, size, and color
  – Can support rich-text
    • Font, size, color, style, and etc.

• Passive UI
  – It does not get any user input.
  – Content will be updated after each application gets input.
  – Support selection, copy/paste, spell correction, auto-completion, etc…
UI Monitor

• Uses library for UI Testing (UIAutomation)
The Gyrus Architecture
Threat Model

• Hypervisor and security VM is fully trusted.
  – Assumes VM escape is impossible.
• Hardware input devices are trusted, and the attacker has no physical access to it.
  – Attacker cannot forge hardware input event
Threat Model (Cont’d)

• All hardware input event is interposed at hypervisor first, then delivered to User VM
  – Security VM cannot miss hardware event, and User VM cannot emulate it.

• We completely distrust User VM
  – We allows all attacks including Kernel-level malware.
    • UI monitor is untrusted.
How Gyrus Works

• Identifying and overlaying all editboxes
  – Only shows for focused window
  – Suppress background update

• Track updates
  – Updates all editbox on
    • Change of focus
    • Change of location
    • Change of content
How Gyrus Works

• On every user interaction, checks whether it triggers traffic
  – Traffic-triggering event
    • Click ‘Send’ button on GMail
    • Pressing ‘ENTER’ on facebook message dialog
    • Pressing Ctrl-S on Outlook Express...
Capture User-Intent

• Extract all required text from Secure Overlay when traffic-triggering event happens.
  – Store it to Authorization DB for enforcement at network level.
Application-specific Logics

- User Intent Signature

Example 1 User Intent Signature for sending e-mail on Windows Live Mail.

```json
{
  "TAG" : "LIVEMAILCOMPOSE",
  "EVENT" : "LCLICK",
  "WINDOW" : "ATH_Note",
  "COND" : {
    "0" : { 
      "CONT" : "BUTTON",
      "NAME" : "Send this message now"
    },
    "2" : { 
      "CONT" : "EDIT",
      "NAME" : "To:
    },
    "3" : { 
      "CONT" : "EDIT",
      "NAME" : "Subject:
    },
    "P-1CCCCCECCC" : { 
      "CONT" : "PANE"
    }
  },
  "CAPTURE" : { 
    "A" : "+2.value",
    "B" : "+3.value",
    "C" : "P-1CCCCCECCC.value"
  },
  "TYPE" : "SMTP",
  "BIND" : { 
    "METHOD" : "SEND",
    "PARAMS" : { 
      "to" : "A",
      "subject" : "B",
      "body" : "C"
    }
  }
}
```
Network Monitor

- A transparent proxy with deep-packet inspection
  - Extract user-intent from the traffic, query authorization DB
    - Pass only when it is matched with stored intent...
  - Requires proxy per each protocol
  - SSL traffic should be decrypted (MITM)
Application Examples
Evaluation

• Security

  – For existing attacks on Apps
    • WYSIWYS is enforced
      – All malware failed to send their traffic on
        » E-mail client (send spam)
        » Internet Messenger (send spam)
        » Facebook (post article, message, and etc.)
        » Paypal (XSS)
        » Etc..
Evaluation

• Security
  – Incorrect User Intent Signature
  – On attacking UI monitor in Guest VM
    • Failure on getting correct information
      – False positive, user traffic will be blocked
      – DoS
Evaluation

• Performance
  – Interaction delay
    • Checked turn-around time starting from the input, end with the resulting text or actions on the Overlay
    • Can handle around 1,400 inputs / min (43ms delay)

<table>
<thead>
<tr>
<th>Actions</th>
<th>Average</th>
<th>STDV</th>
<th>Median</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typing</td>
<td>39ms</td>
<td>21ms</td>
<td>34ms</td>
<td>128ms</td>
</tr>
<tr>
<td>ENTER</td>
<td>19ms</td>
<td>6ms</td>
<td>17ms</td>
<td>43ms</td>
</tr>
<tr>
<td>LCLICK</td>
<td>43ms</td>
<td>15ms</td>
<td>41ms</td>
<td>79ms</td>
</tr>
<tr>
<td>Focus Change</td>
<td>21ms</td>
<td>19ms</td>
<td>17ms</td>
<td>158ms</td>
</tr>
<tr>
<td>Move &amp; Resize</td>
<td>21ms</td>
<td>16ms</td>
<td>16ms</td>
<td>85ms</td>
</tr>
</tbody>
</table>

**TABLE II.** Latency introduced by Gyrus while processing the input. User-interaction data was collected during the use case evaluation.
Evaluation

- Performance
  - Network delay

<table>
<thead>
<tr>
<th>Cases</th>
<th>KVM</th>
<th>Gyrus</th>
<th>Overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single (A)</td>
<td>101.7ms</td>
<td>102.3ms</td>
<td>+0.6ms (.5%)</td>
</tr>
<tr>
<td>Single (B)</td>
<td>31.20ms</td>
<td>32.30ms</td>
<td>+1.1ms (3.5%)</td>
</tr>
<tr>
<td>Web Page</td>
<td>897.5ms</td>
<td>951.3ms</td>
<td>+53.8ms (6%)</td>
</tr>
<tr>
<td>Download</td>
<td>51.1MB/s</td>
<td>49.3MB/s</td>
<td>−1.8MB/s (3.5%)</td>
</tr>
</tbody>
</table>

**TABLE III.** NETWORK LATENCY FOR HTTP CONNECTION.

<table>
<thead>
<tr>
<th>Cases</th>
<th>KVM</th>
<th>Gyrus</th>
<th>Overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Request</td>
<td>90.72ms</td>
<td>94.50ms</td>
<td>+3.78ms (4%)</td>
</tr>
<tr>
<td>Download</td>
<td>37.40MB/s</td>
<td>35.23MB/s</td>
<td>−2.17MB/s (5.8%)</td>
</tr>
</tbody>
</table>

**TABLE IV.** NETWORK LATENCY FOR HTTPS CONNECTION (WITH MAN-IN-THE-MIDDLE PROXY).
Limitations

• Can only handle text so far.....
  – File/Image attachments
    • What we see: name of path (e.g., c:\boot.ini)
    • What machine sends: content of the file
    • Using ACG would be helpful

• Only works if what you see is really what you send
  – Not the case if displayed text undergone a lot of (proprietary) processing before being sent out.
  – However, base64, SSL, and REST API through HTTPS can be handled.
Conclusion

• Gyrus
  – A correct-behavior based monitoring system.
  – Monitors user-intended text through on-screen UI data, and enforcing WYSIWYS policy.
  – Protect most of text-based user applications with minimal overhead.
  – Its attack-agnostic defense works for preventing future attacks.
Questions?

• Q&A
Discussions

• Attacks on UI monitor
  – Malware that tries to modify text
    • At network monitor, it only allows text in the authorization DB.
    • Authorization DB only stores on-screen text.
    • => The text content malware would send should be on-screen.
    • => User will be notified from on-screen changes.
Future Works

• Implement in different platform
  – Android (DalVik VM)
  – Thin-client model, a terminal for cloud service

• Protect different target
  – Disk write (think disk operation as a network traffic)

• Confidentiality protection
  – Gyrus only protects integrity of user intent.