Building Trust in the User I/O in Computer Systems

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Problem Statement

- User I/O is important
  - Input controls system / output contains sensitive data
  - User input/output makes security decision

- Many attack points on the systems
  - Neither isolated nor protected
  - Attackers modify / inject / eavesdrop I/O data

Thesis Scope

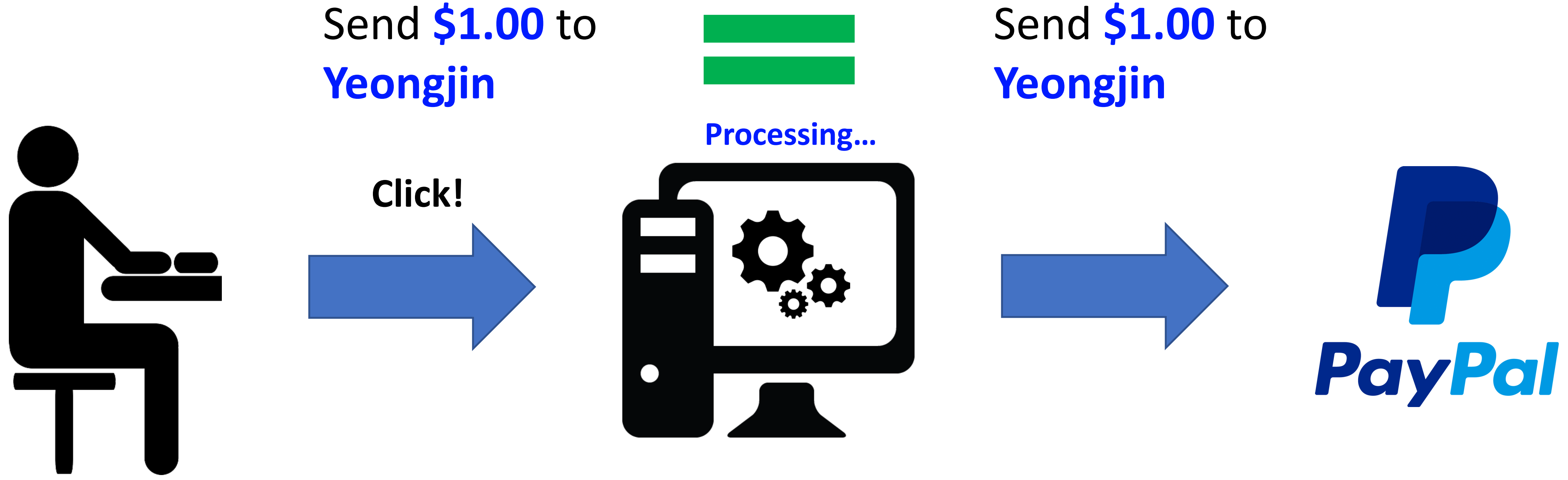
- Building trusted user I/O path in computer systems
  - Do not let attacker intervene in the I/O path

- Approaches
  - Analyze systems' user I/O paths and threats on them
  - Build security mechanisms to block attack pathways by guaranteeing:
    - Integrity
    - Confidentiality
    - Authenticity

Thesis Topics

- Integrity of User Input
  - Gyrus – authorizing network traffic output using user input information
- Confidentiality of User I/O
  - M-aegis – providing end-to-end encryption of user I/O in messaging apps
- Authenticity of User I/O
  - A11y attacks – presenting attacks caused by missing authenticity check
- Assurance of User I/O
  - SGX-USB – establishing a secure USB I/O channel in Intel SGX

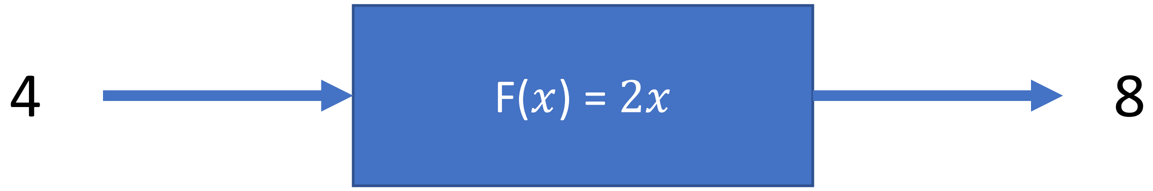
Gyrus: Protecting the Integrity of User Input



Motivation

- User controls system by supplying input

- Think a computer as a function:
  - On user’s input, there will be an output



- Can we make a system that only generates a “correct” output that correspond to the input?

Matching Network Output to User Input

- User types ”send $1.00 to Yeongjin”
  - Expected network output: send ***$1.00*** to ***Yeongjin***
- A malware in the system can alter the value of network output
  - Malicious network output: send ***$1000.00*** to ***Bob***
- But, ***user input*** has the correct values

Send **$1.00** to **Yeongjin**

Can we use utilize ***user inputs*** as basis for
a correct behavior to block attacks?
E.g., only allow the ***traffic that matches with user input***

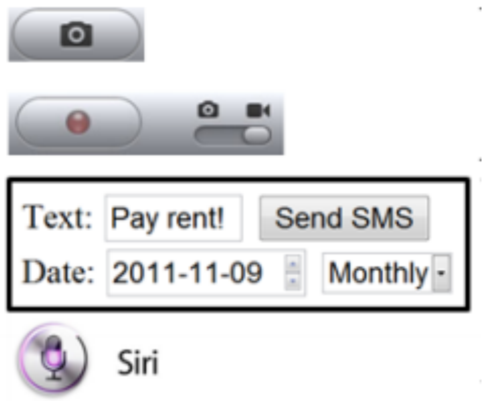
Related Work

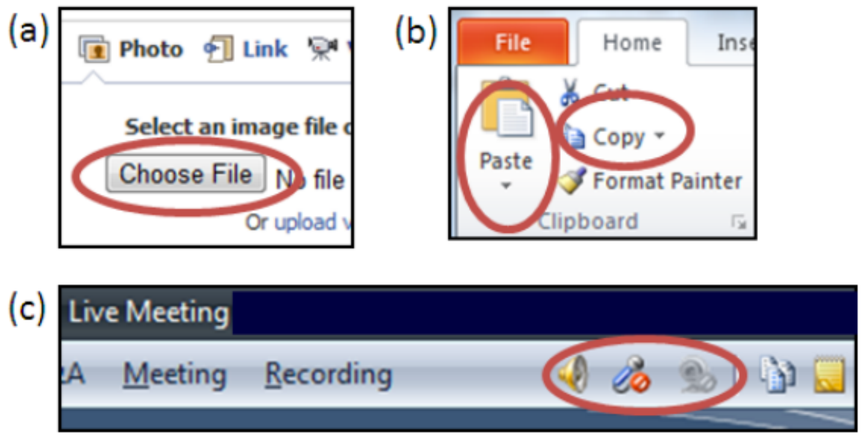
- Use Timing Information for User Intent Detection
  - BINDER [Cui et al., ACSAC ‘05]
  - Not-A-Bot [Gummadi et al., NSDI ‘09]

- Method
  - Monitor physical keystroke/mouse clicks
  - A network packet sent within a short-time after user action is user intended
    - $T_{network} – T_{input} < T_{threshold}$
    - E.g., packet sent 500ms after user’s action

Related Work

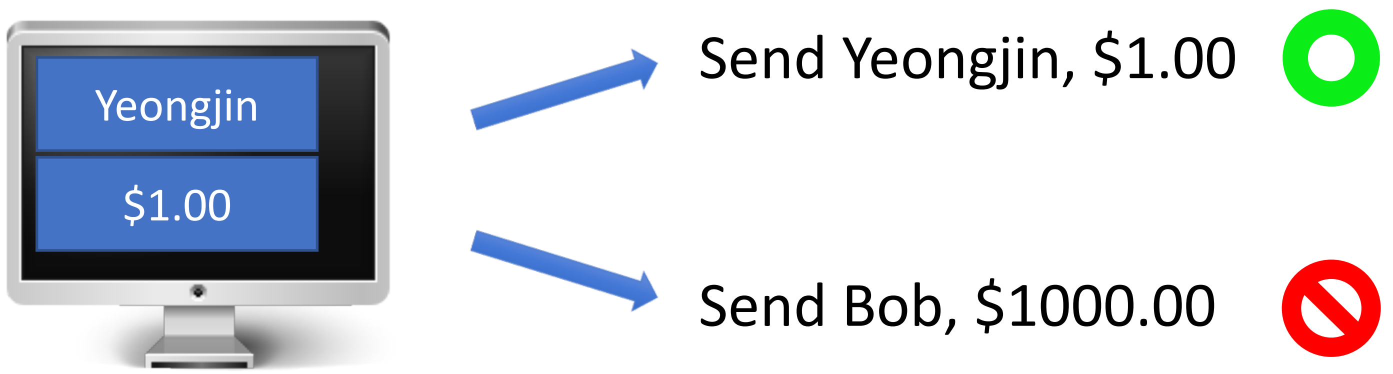
- Use UI Widget for User Intent Detection
  - User-driven Access Control [Roesner et al., Oakland ’12]
- Bind permissions with UI widget
  - Only grant permission to resource if the user clicks a widget





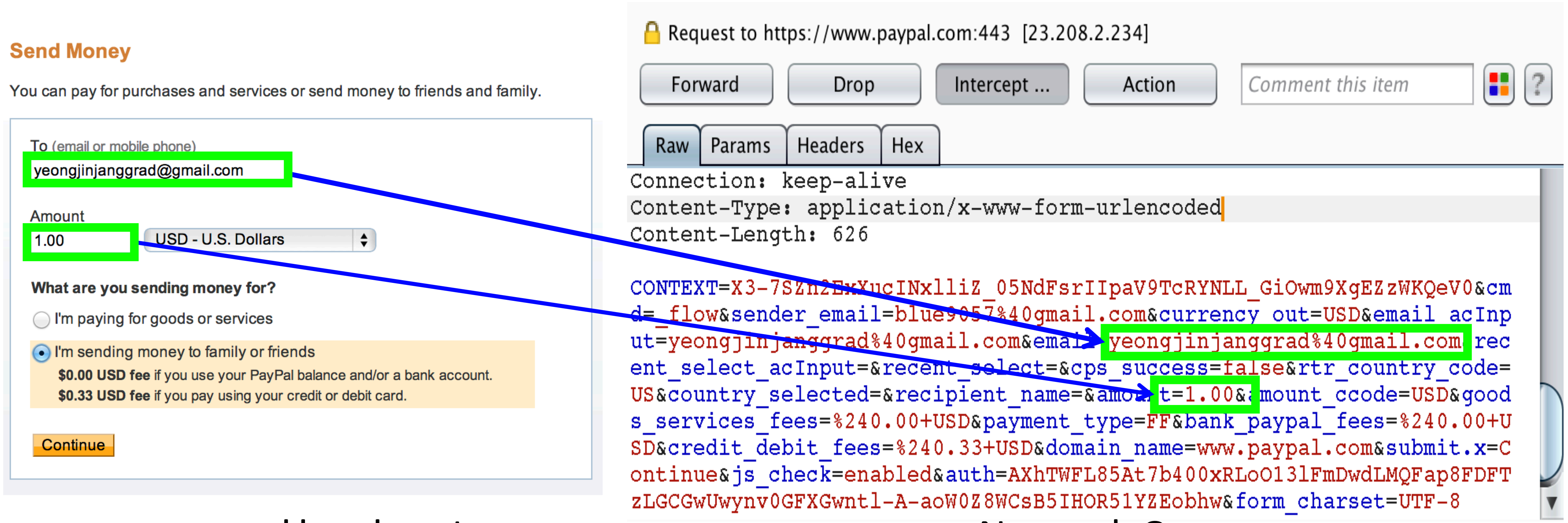
Use On-screen Text as User’s Intention

- New security policy: What You See is What You Send (WYSIWYS)
  - Assume on-screen text is user-intended input
  - Only allow outgoing traffic that matches to on-screen text



Examples

- We can infer expected ***network output*** from ***on-screen text***



Send Money

You can pay for purchases and services or send money to friends and family.

To (email or mobile phone): yeongjinjanggrad@gmail.com

Amount: 1.00 USD - U.S. Dollars

What are you sending money for?

( ) I'm paying for goods or services

(●) I'm sending money to family or friends
$0.00 USD fee if you use your PayPal balance and/or a bank account.
$0.33 USD fee if you pay using your credit or debit card.

```
Connection: keep-alive
Content-Type: application/x-www-form-urlencoded
Content-Length: 626

CONTEXT=X3-7SZn2ExXucINxlliZ_05NdFsrIIpaV9TcRYNLL_GiOwm9XgEZzWKQeV0&cm
d=_flow&sender_email=blue9057%40gmail.com&currency_out=USD&email_acInp
ut=yeongjinjanggrad%40gmail.com&email=yeongjinjanggrad%40gmail.com&rec
ent_select_acInput=&recent_select=&cps_success=false&rtr_country_code=
US&country_selected=&recipient_name=&amount=1.00&amount_ccode=USD&good
s_services_fees=%240.00+USD&payment_type=FF&bank_paypal_fees=%240.00+U
SD&credit_debit_fees=%240.33+USD&domain_name=www.paypal.com&submit.x=C
ontinue&js_check=enabled&auth=AXhTWFL85At7b400xRLoO131FmDwdLMQFap8FDFT
zLGCGwUwynv0GFXGwntl-A-aoW0Z8WCsB5IHOR51YZEobhw&form_charset=UTF-8
```

User Input　　　　　　Network Output

Cases of WYSIWYS

- Internet Messenger
  - Messaging, e-mail, etc.
- Submitting text-forms
  - Online banking, online social network (facebook), etc.

- Not WYSIWYS
  - Uploading files
  - Encrypted traffic -> Man-in-the-middle proxy can handle standard encryption(TLS)

Threat Model

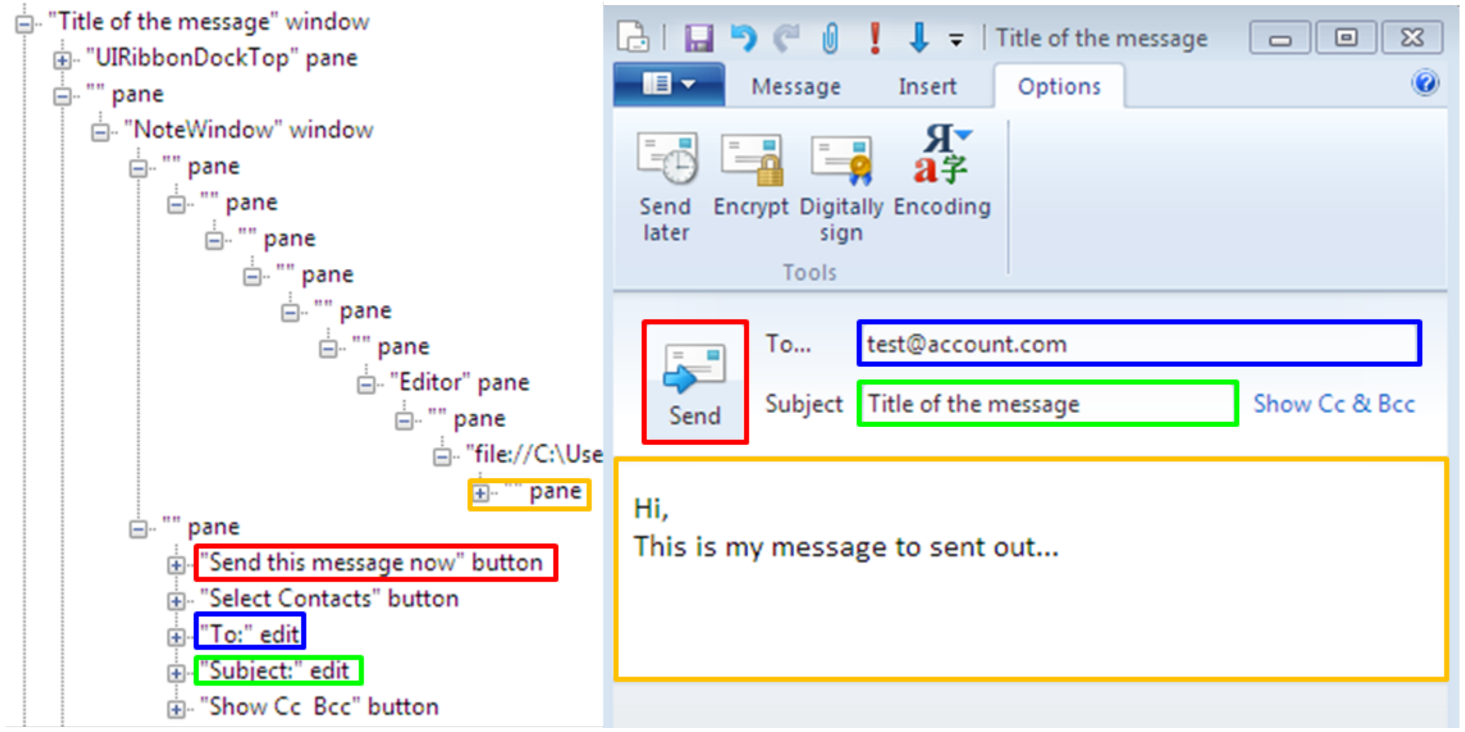
- Not trusted
  - OS and all lower privileged programs
- Trusted
  - Virtual machine monitor and programs in dom0
  - Input devices
  - Display device
- No physical access to the machine

Design

- Capturing User-intended Input
  - What you see
- Monitoring Network Traffic
  - What you send
- Protecting Security Monitor
  - A secure way of matching what you see and what you send

Read On-screen Text from UI Elements

- UIAutomation



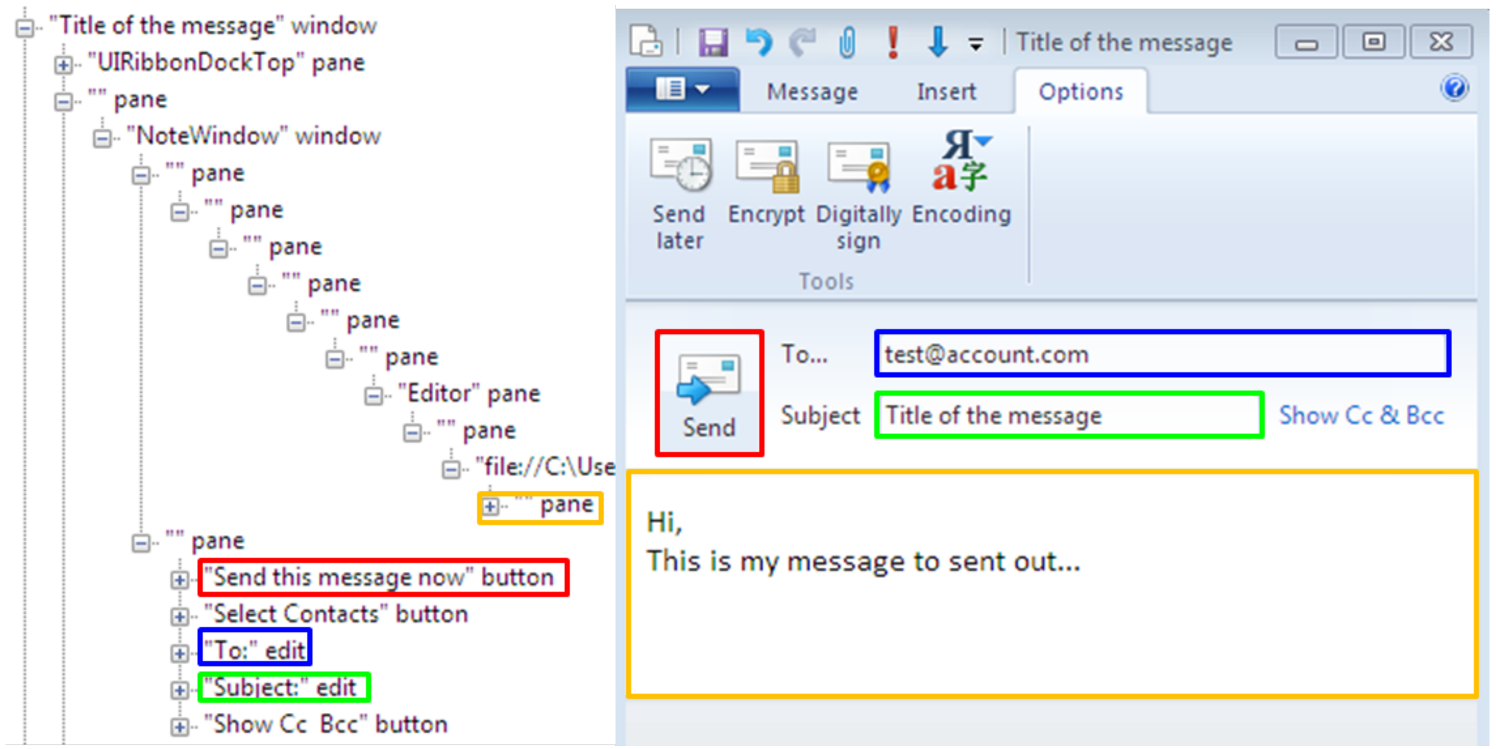
```
"Title of the message" window
  "UIRibbonDockTop" pane
  "" pane
    "NoteWindow" window
      "" pane
        "" pane
          "" pane
            "" pane
              "" pane
                "" pane
                  "Editor" pane
                    "" pane
                      "file://C:\Use
                        "" pane
      "" pane
        "Send this message now" button
        "Select Contacts" button
        "To:" edit
        "Subject:" edit
        "Show Cc  Bcc" button
```

To... test@account.com

Subject Title of the message

Hi,
This is my message to sent out...

Per-application Signature



```
"Title of the message" window
  "UIRibbonDockTop" pane
  "" pane
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      "" pane
        "" pane
          "" pane
            "" pane
              "" pane
                "" pane
                  "Editor" pane
                    "" pane
                      "file://C:\Use
                        "" pane
      "" pane
        "Send this message now" button
        "Select Contacts" button
        "To:" edit
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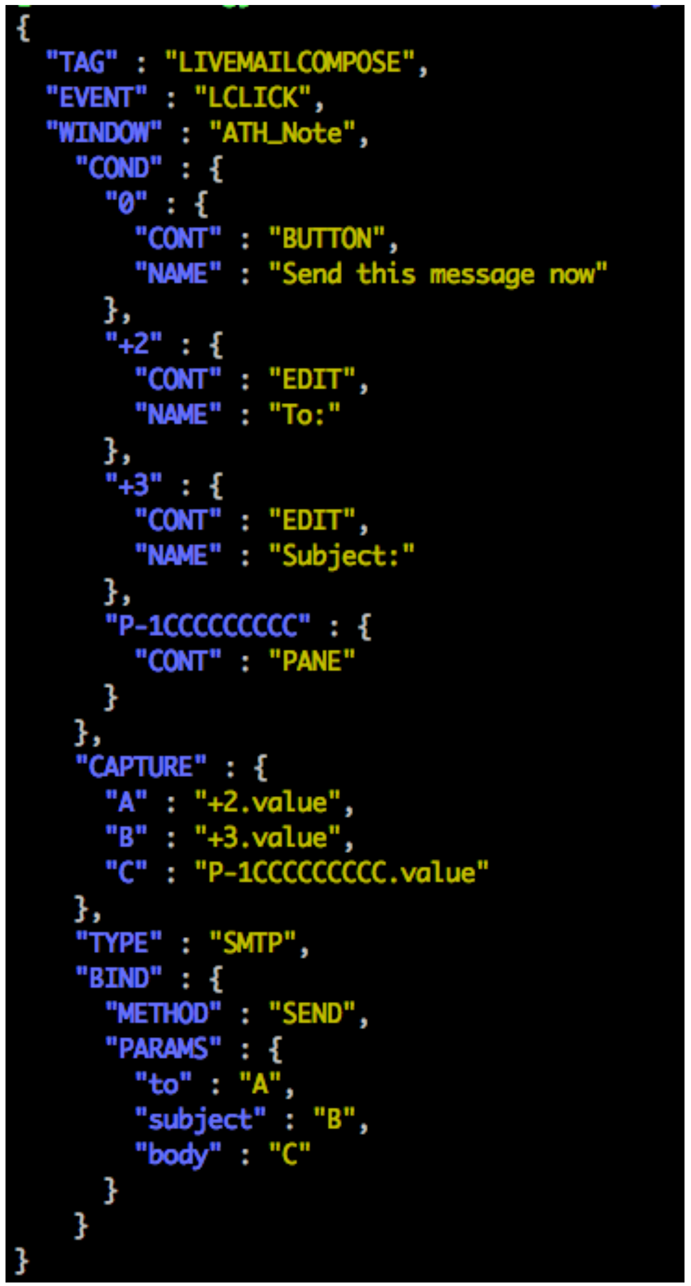
To... test@account.com

Subject Title of the message

Hi,
This is my message to sent out...



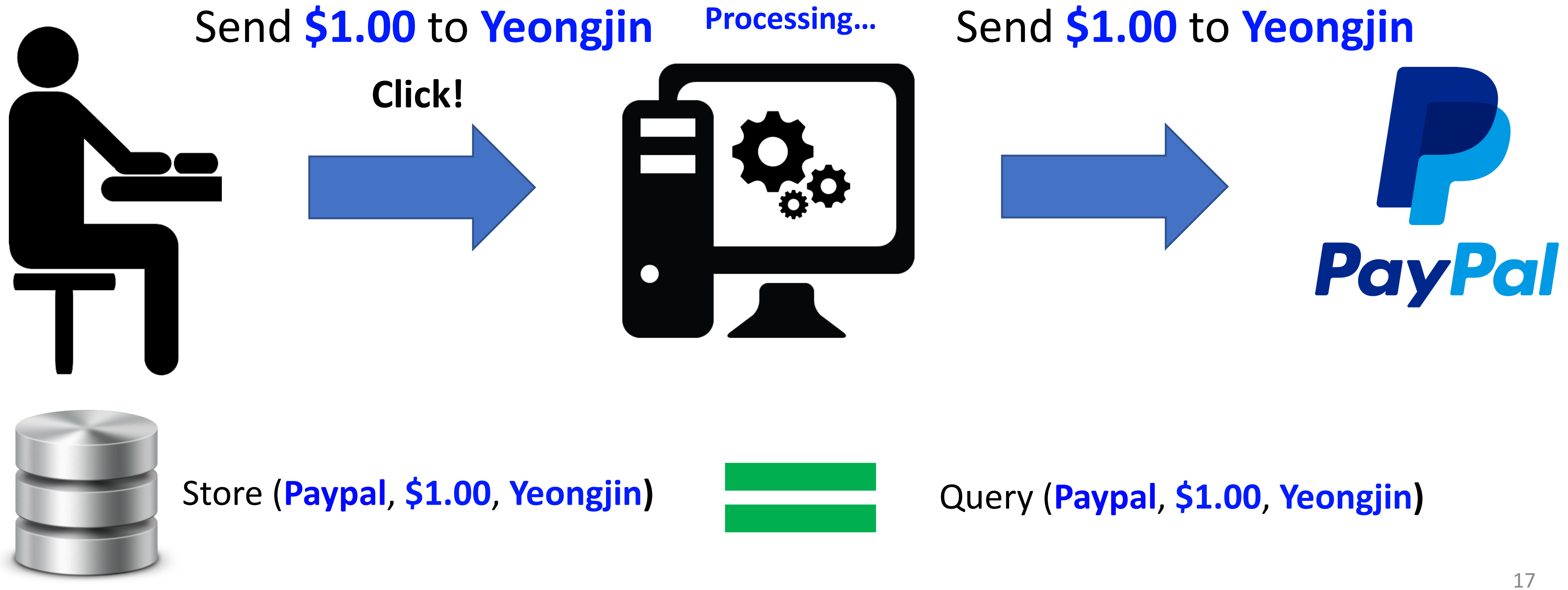
```
{
  "TAG" : "LIVEMAILCOMPOSE",
  "EVENT" : "LCLICK",
  "WINDOW" : "ATH_Note",
    "COND" : {
      "0" : {
        "CONT" : "BUTTON",
        "NAME" : "Send this message now"
      },
      "+2" : {
        "CONT" : "EDIT",
        "NAME" : "To:"
      },
      "+3" : {
        "CONT" : "EDIT",
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

Monitoring Network Traffic

- Deep packet inspection
  - Redirect network traffic into a proxy, then inspect the content
- Encrypted traffic
  - Use man-in-the-middle proxy to decrypt, inspect, then encrypt again
- Text transformation
  - We can apply same transformation to the user input
  - E.g., ”Hi there” -> Hi%20there

Monitoring Network Traffic

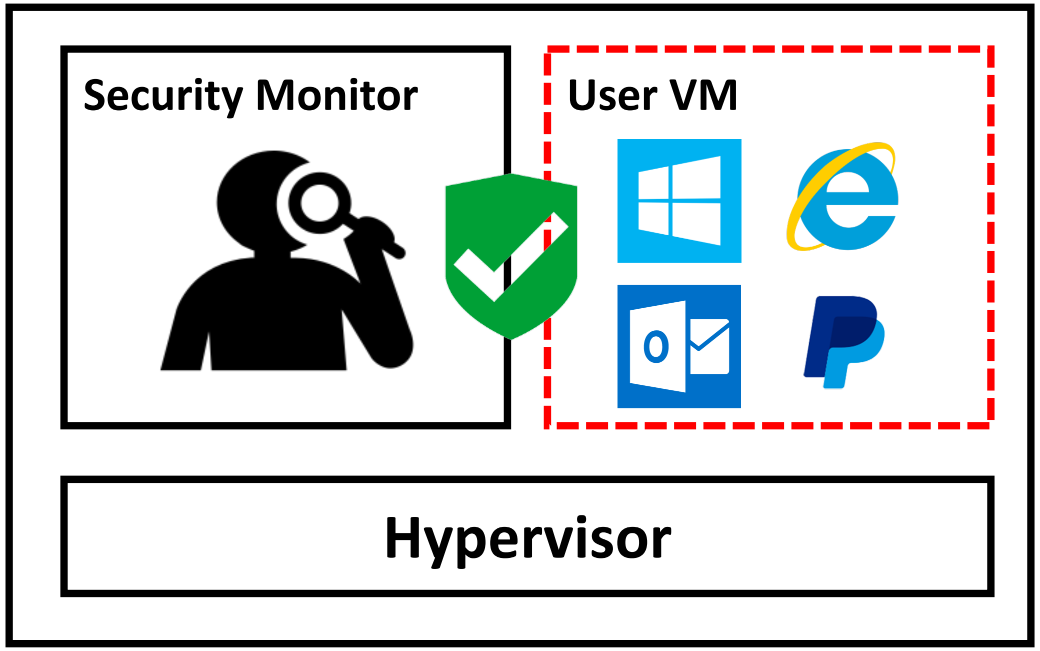
- Use database to store user interaction data


Send **$1.00** to **Yeongjin**
Click!
Processing…
Send **$1.00** to **Yeongjin**
PayPal
Store (**Paypal**, **$1.00**, **Yeongjin**)
=
Query (**Paypal**, **$1.00**, **Yeongjin**)

Protecting Security Monitor

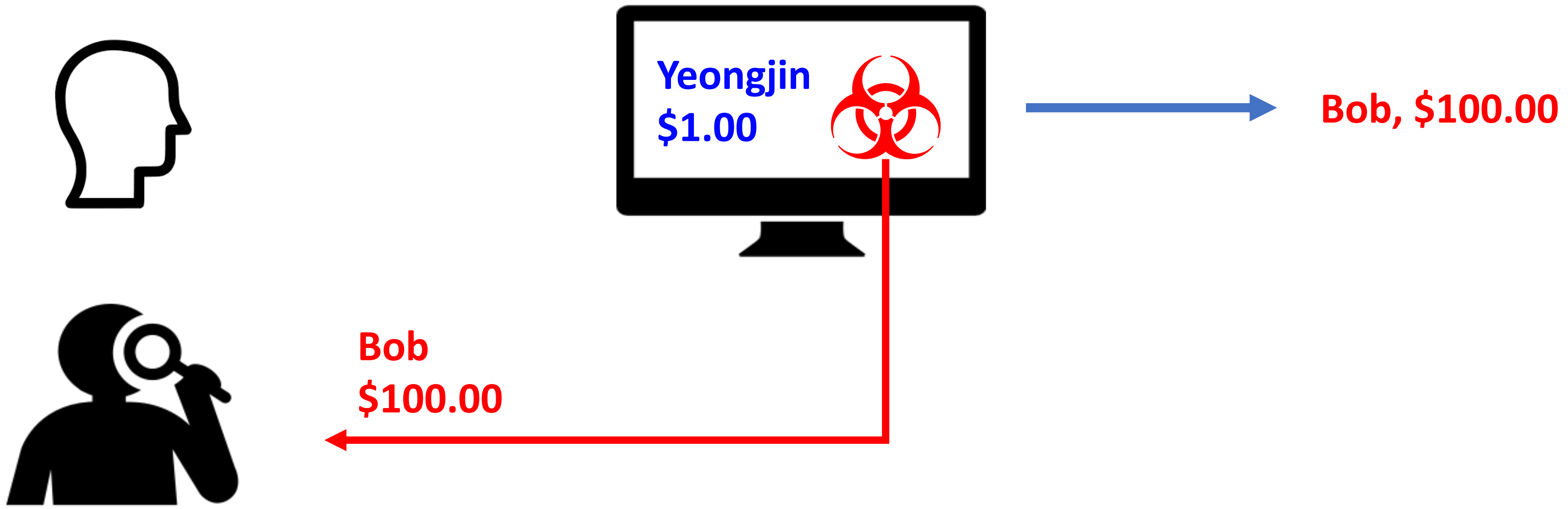
- Modern malwares have the highest privilege in OS (i.e., root)
  - To monitor the system, we need more higher privilege

- Virtual machine isolation
  - Hypervisor isolates security monitor
  - User VM cannot attack security monitor
  - Security monitor can inspect User VM through Hypervisor

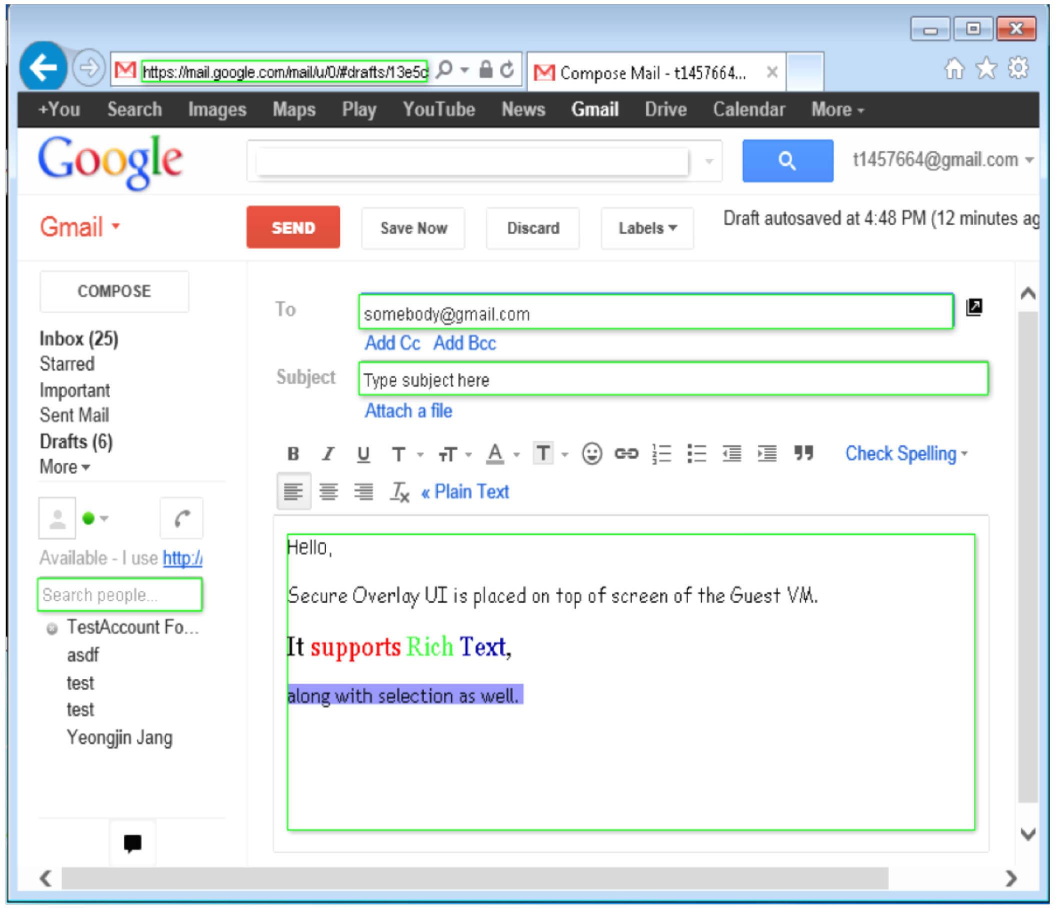


Data from User VM is not Trustful

- UIAutomation data from User VM
- Attackers can alter the data
  - On screen: send Yeongjin $1.00
  - On UI Element: send Bob $100.00
  - The system will catch (Bob, $100) instead of (Yeongjin, $1.00)



Security Overlay



Draft autosaved at 4:48 PM (12 minutes ag

To: somebody@gmail.com

Subject: Type subject here

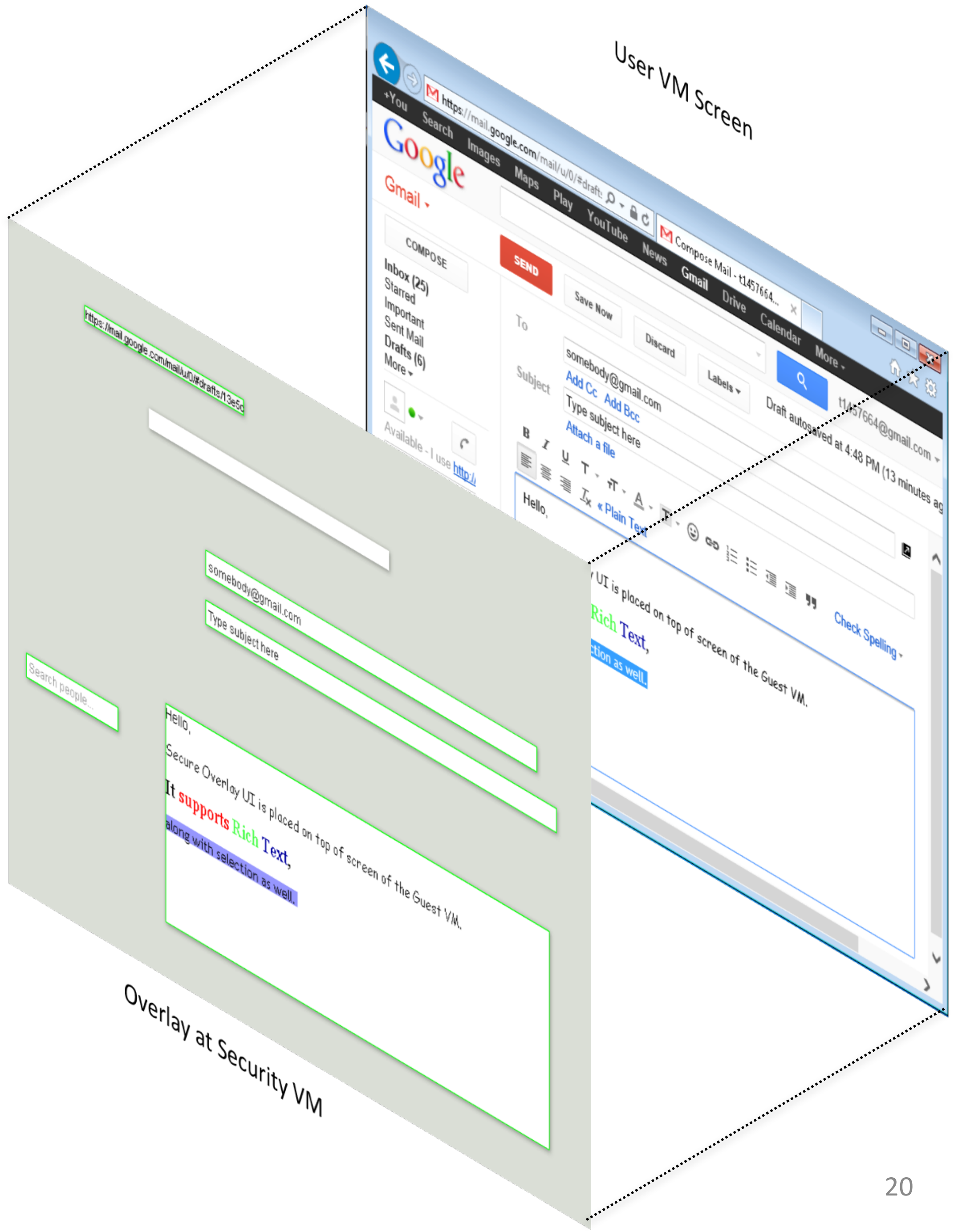
Hello,

Secure Overlay UI is placed on top of screen of the Guest VM.

It supports Rich Text,

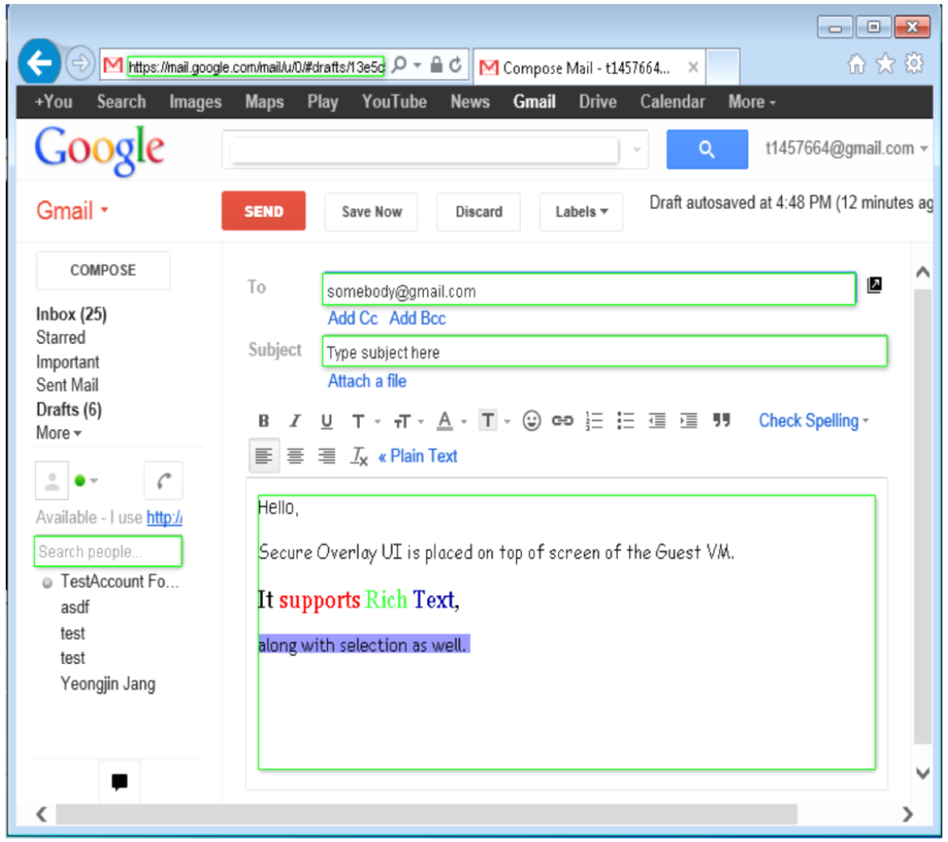
along with selection as well.

Combined Screen



What You See == What Monitor Captured

- Receive UI data from untrusted VM
- Re-draws all editboxes in secure domain
  - Draw at the exactly same location, size, etc.
  - Update text on each change (Autocomplete)
- User will only see the data at the overlay
  - Make sure our security monitor correctly capture the intended text



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To: somebody@gmail.com

Subject: Type subject here

Hello,

Secure Overlay UI is placed on top of screen of the Guest VM.

It supports Rich Text,

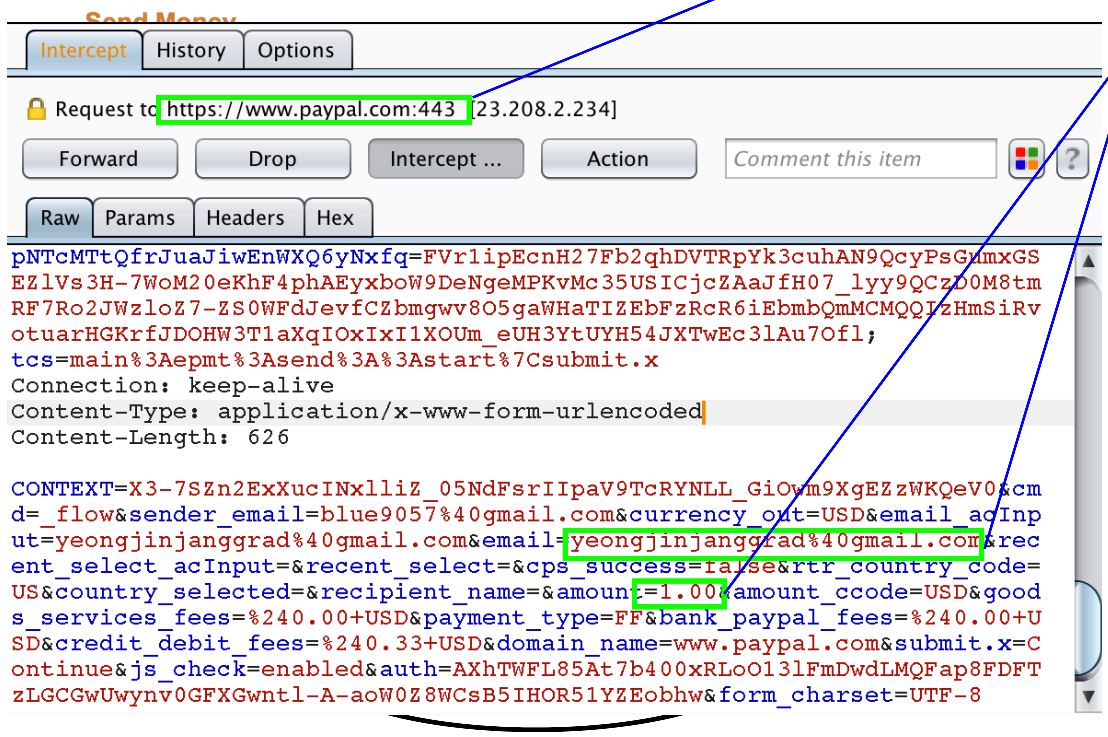
along with selection as well.

Gyrus Workflow with Paypal

Matched!

“ACTION” : “Paypal Send”,
“Recipient” : yeongjinjanggrad@gmail.com,
“Amount” : “1.00”

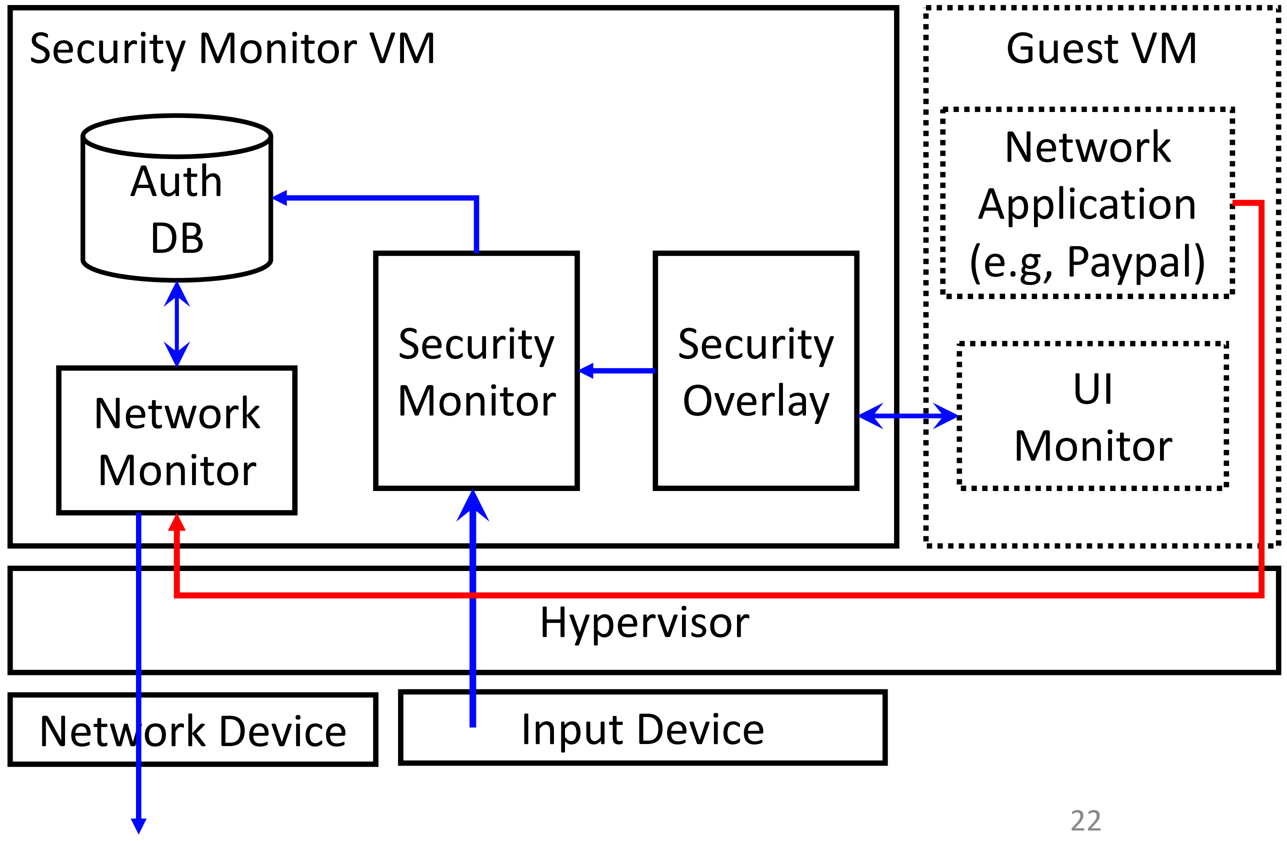
Authorization Vector



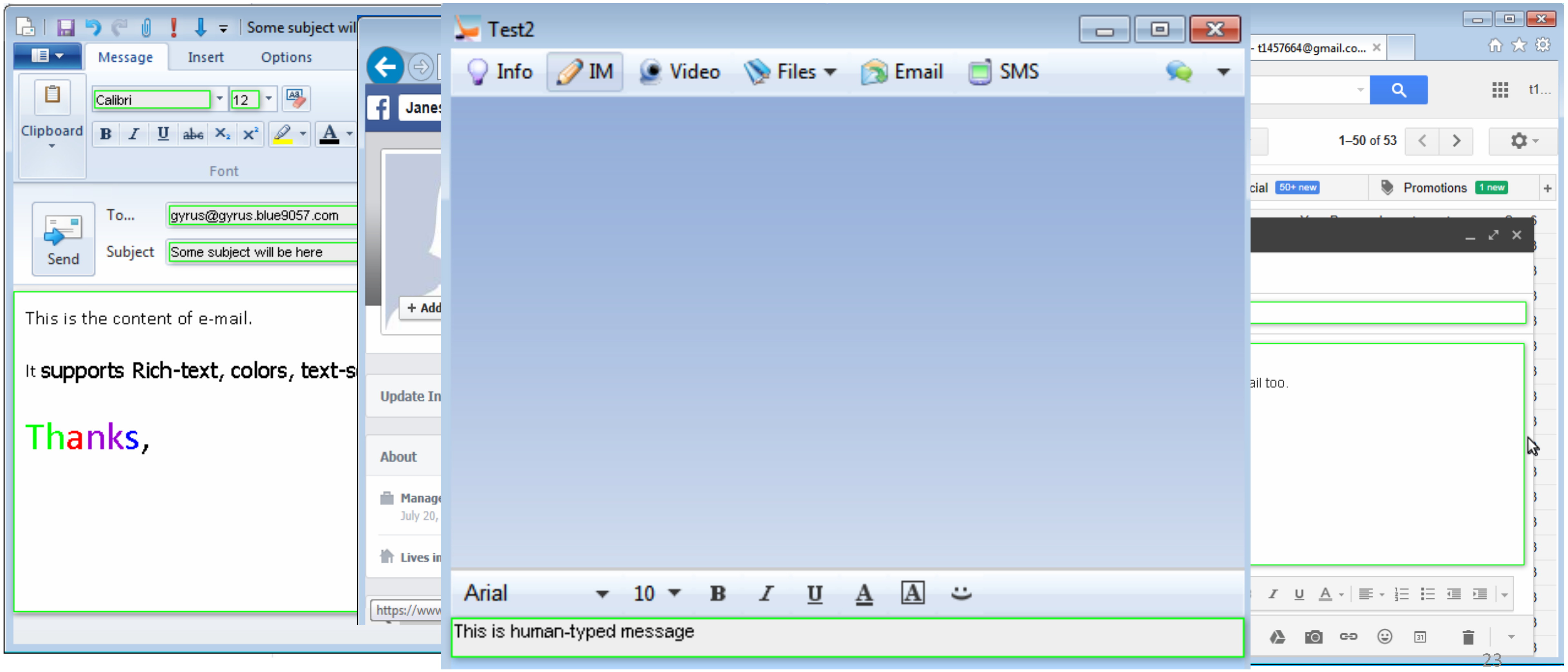
Request to https://www.paypal.com:443 [23.208.2.234]

```
pNTcMTtQfrJuaJiwEnWXQ6yNxfq=FVr1ipEcnH27Fb2qhDVTRpYk3cuhAN9QcyPsGumxGS
EZ1Vs3H-7WoM20eKhF4phAEyxboW9DeNgeMPKvMc35USICjcZAaJfH07_lyy9QCzD0M8tm
RF7Ro2JWzloZ7-ZS0WFdJevfCZbmgwv805gaWHaTIZEbFzRcR6iEbmbQmMCMQQIzHmSiRv
otuarHGKrfJDOHW3T1aXqIOxIxI1XOUm_eUH3YtUYH54JXTwEc3lAu7Ofl;
tcs=main%3Aepmt%3Asend%3A%3Astart%7Csubmit.x
Connection: keep-alive
Content-Type: application/x-www-form-urlencoded
Content-Length: 626

CONTEXT=X3-7SZn2ExXucINxlliZ_05NdFsrIIpaV9TcRYNLL_GiOwm9XgEZzWKQeV0&cm
d=_flow&sender_email=blue9057%40gmail.com&currency_out=USD&email_acInp
ut=yeongjinjanggrad%40gmail.com&email=yeongjinjanggrad%40gmail.com&rec
ent_select_acInput=&recent_select=&cps_success=false&rtr_country_code=
US&country_selected=&recipient_name=&amount=1.00&amount_ccode=USD&good
s_services_fees=%240.00+USD&payment_type=FF&bank_paypal_fees=%240.00+U
SD&credit_debit_fees=%240.33+USD&domain_name=www.paypal.com&submit.x=C
ontinue&js_check=enabled&auth=AXhTWFL85At7b400xRLoO13lFmDwdLMQFap8FDFT
zLGCGwUwynv0GFXGwntl-A-aoW0Z8WCsB5IHOR51YZEobhw&form_charset=UTF-8
```



Application Examples



To... gyrus@gyrus.blue9057.com

Subject: Some subject will be here

This is the content of e-mail.

It supports Rich-text, colors, text-s

Thanks,

This is human-typed message

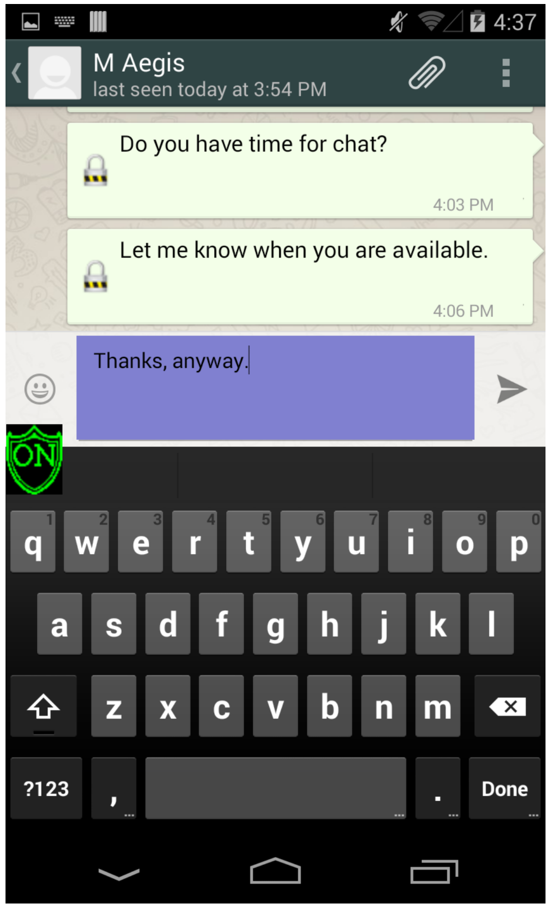
ail too.

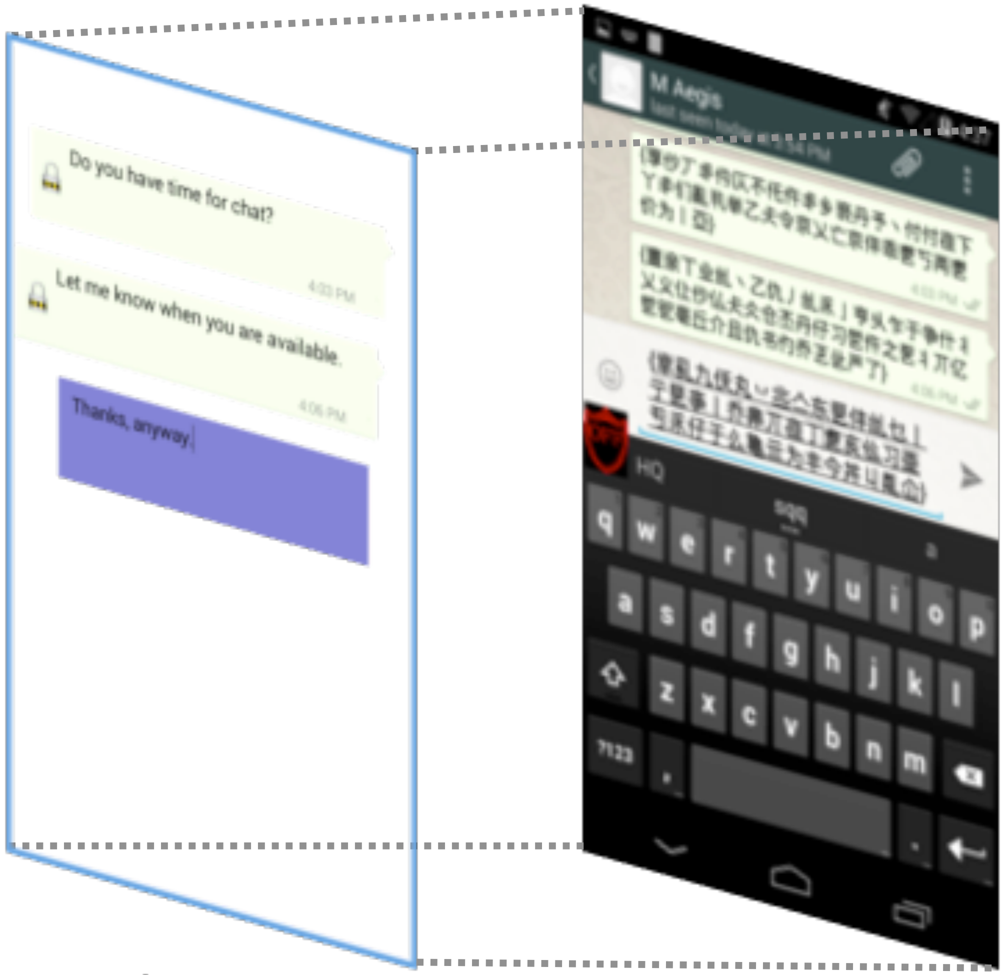
Evaluations

- No traffic can go out without having proper user interaction
  - All transactions sent from malware was blocked
  - Attacker can still launch denial of service attack
    - **Fail-safe:** no attack traffic can go out

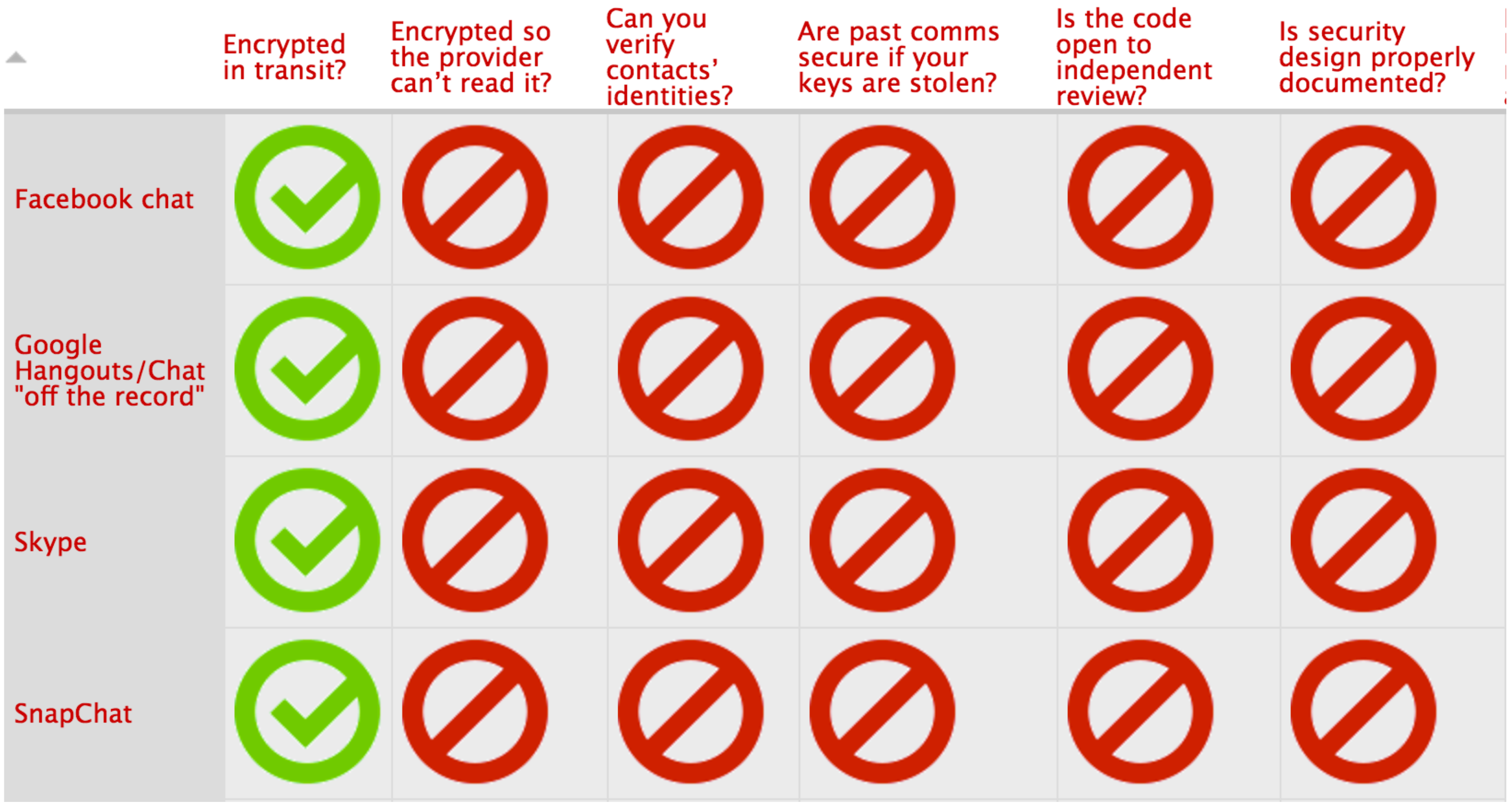
- Negligible overhead on interposing user input and network monitoring
  - Adding 34ms of delay on click
  - ~50ms of delay on webpage load, 3% overhead on bandwidth

M-Aegis: Protecting the Confidentiality of User Input/Output


M Aegis
last seen today at 3:54 PM
Do you have time for chat?
4:03 PM
Let me know when you are available.
4:06 PM
Thanks, anyway.



The Status Quo: Encryption for Messengers



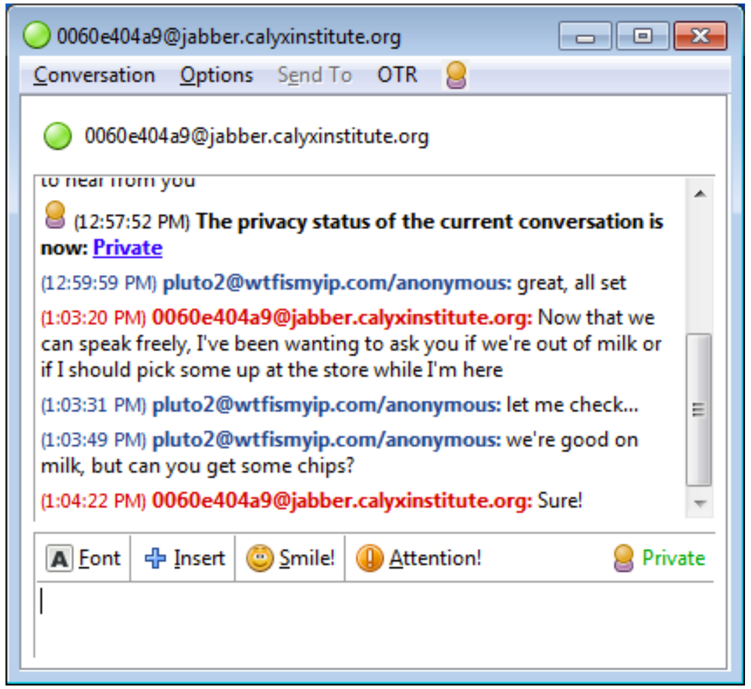
	Encrypted in transit?	Encrypted so the provider can't read it?	Can you verify contacts' identities?	Are past comms secure if your keys are stolen?	Is the code open to independent review?	Is security design properly documented?
Facebook chat	✓	⊘	⊘	⊘	⊘	⊘
Google Hangouts/Chat "off the record"	✓	⊘	⊘	⊘	⊘	⊘
Skype	✓	⊘	⊘	⊘	⊘	⊘
SnapChat	✓	⊘	⊘	⊘	⊘	⊘

Standalone Solutions

- Protect data confidentiality
- Good isolation from untrusted entities

- Examples:
  - PGP, Pidgin, TextSecure, SafeSlinger, FlyByNight, etc.

- Problem:
  - Requires open protocol
  - Do not preserve user experience


0060e404a9@jabber.calyxinstitute.org
Conversation
Options
Send To
OTR
0060e404a9@jabber.calyxinstitute.org
Font
Insert
Smile!
Attention!
Private

to hear from you

(12:57:52 PM) **The privacy status of the current conversation is now: Private**

(12:59:59 PM) **pluto2@wtfismyip.com/anonymous:** great, all set

(1:03:20 PM) **0060e404a9@jabber.calyxinstitute.org:** Now that we can speak freely, I've been wanting to ask you if we're out of milk or if I should pick some up at the store while I'm here

(1:03:31 PM) **pluto2@wtfismyip.com/anonymous:** let me check...

(1:03:49 PM) **pluto2@wtfismyip.com/anonymous:** we're good on milk, but can you get some chips?

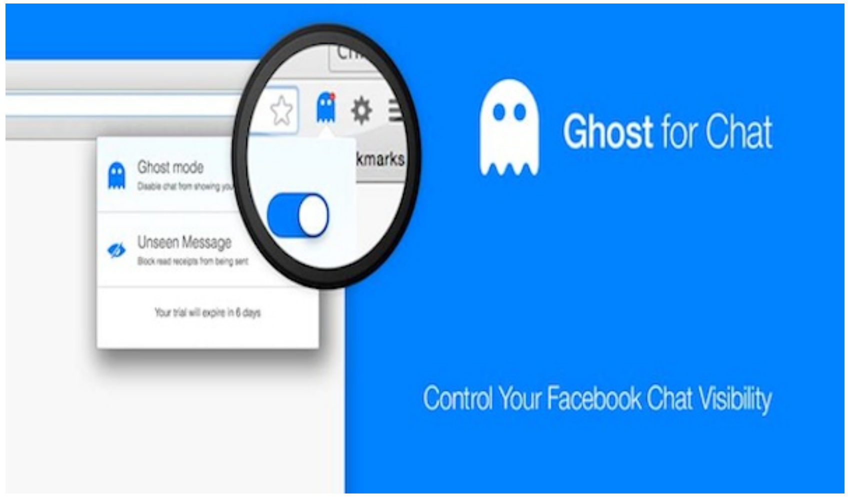
(1:04:22 PM) **0060e404a9@jabber.calyxinstitute.org:** Sure!

Browser Plugins/Extensions

- Provides transparent integration with applications of interest

- Examples:
  - Ghost for chat, TrustSplit, NOYB, SafeButton, etc.

- Problem: Only applicable to web applications.
  - How about native apps and mobile devices?


Ghost mode
Unseen Message
Your trial will expire in 6 days
kmarks
Ghost for Chat
Control Your Facebook Chat Visibility

M-Aegis: Design Goals

- Targets native applications and mobile devices
- Offer good security
  - End-to-end encryption, and strong isolation from untrusted entities
- Preserve user experience
  - Transparent interaction with existing apps
- Does not require protocol reverse engineering
  - A sufficiently general-purpose approach

- Out-of-scope: Key exchange
  - We assume key exchange can be done by other means (out-of-band).

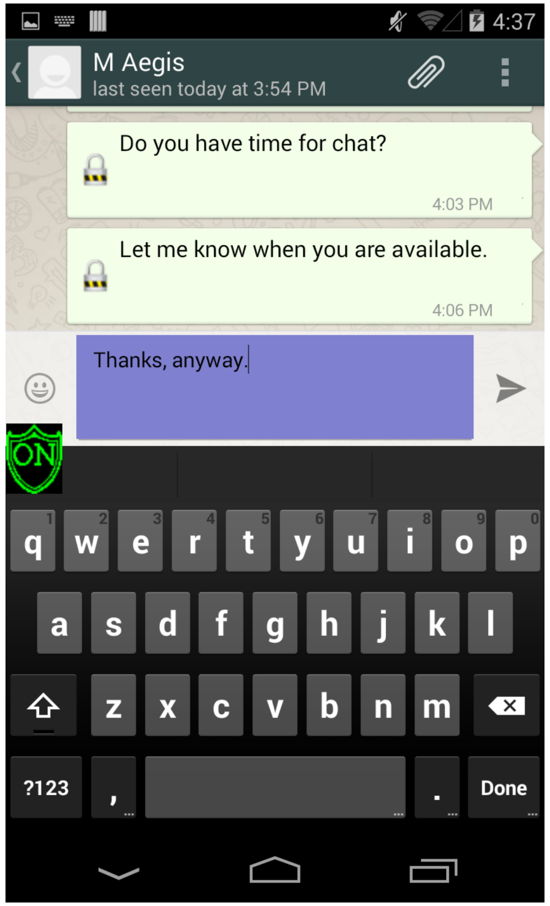
Threat Model

- Untrusted parties:
  - Service providers
  - Client-side apps
  - Middle boxes between a service provider and the client-side app

- Trusted components:
  - Hardware, OS
  - Soft keyboard
  - Components of M-Aegis

M-Aegis Architecture

- Layer 7.5

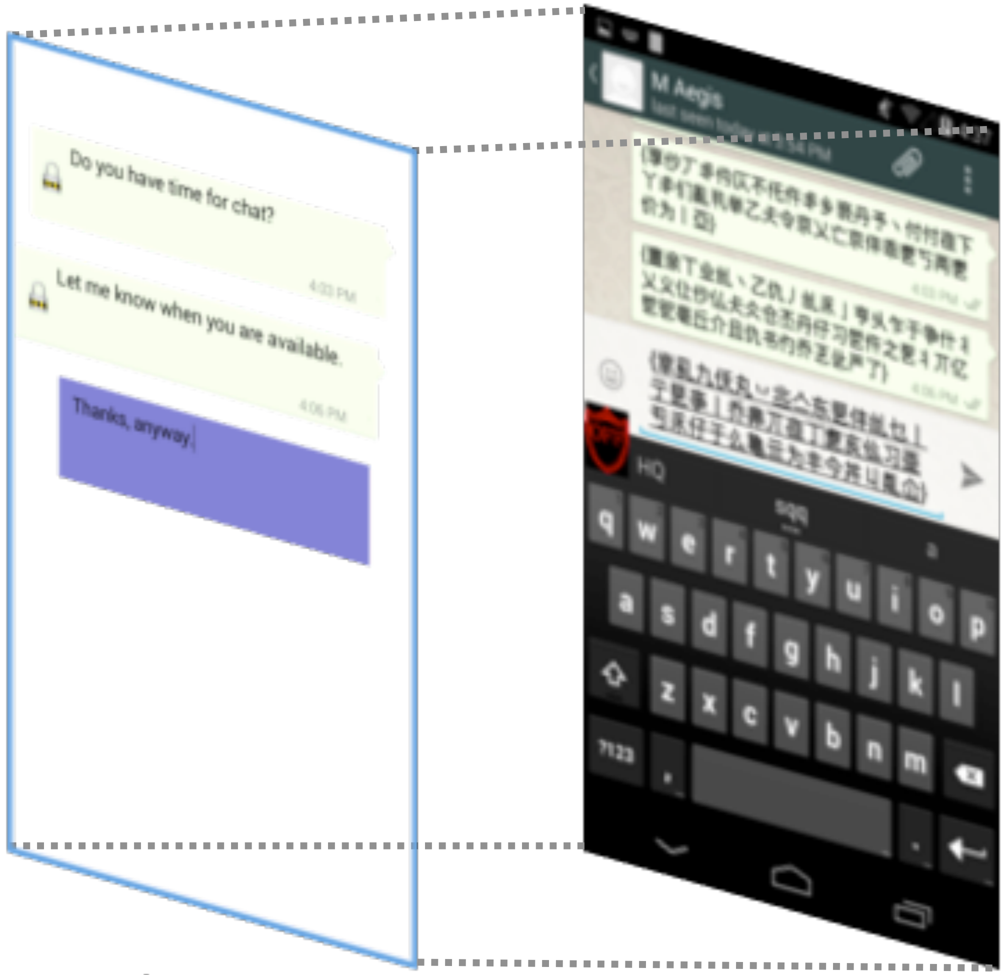


M Aegis
last seen today at 3:54 PM

Do you have time for chat? 4:03 PM

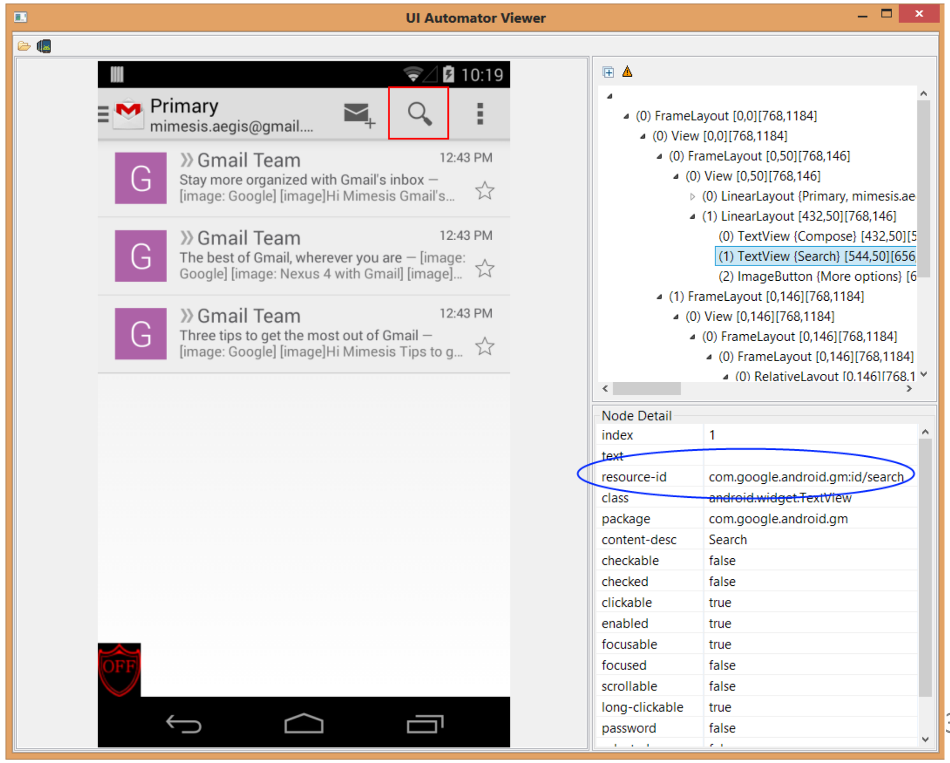
Let me know when you are available. 4:06 PM

Thanks, anyway.


Do you have time for chat?
Let me know when you are available.
Thanks, anyway.
M Aegis

M-Aegis Architecture

- UI Automation Manager (UIAM)
  - Gives M-Aegis the context of the screen
  - Provides information to correctly render mimic GUIs on L-7.5
  - Relays user touch to the underlying app



UI Automator Viewer
10:19
Primary
mimesis.aegis@gmail....
Gmail Team
12:43 PM
Stay more organized with Gmail's inbox –
[image: Google] [image]Hi Mimesis Gmail's...
Gmail Team
12:43 PM
The best of Gmail, wherever you are – [image:
Google] [image: Nexus 4 with Gmail] [image]...
Gmail Team
12:43 PM
Three tips to get the most out of Gmail –
[image: Google] [image]Hi Mimesis Tips to g...
OFF

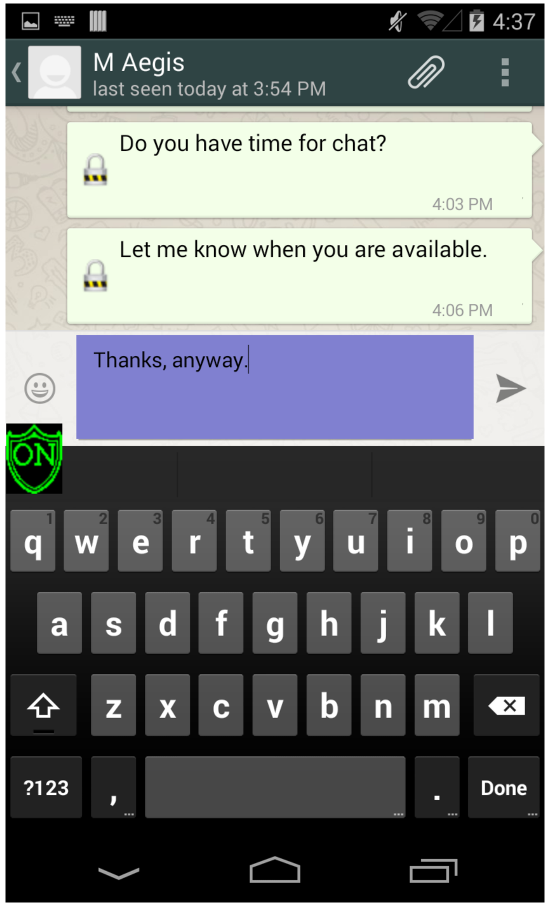
```
(0) FrameLayout [0,0][768,1184]
  (0) View [0,0][768,1184]
    (0) FrameLayout [0,50][768,146]
      (0) View [0,50][768,146]
        (0) LinearLayout {Primary, mimesis.ae
        (1) LinearLayout [432,50][768,146]
          (0) TextView {Compose} [432,50][5
          (1) TextView {Search} [544,50][656
          (2) ImageButton {More options} [6
    (1) FrameLayout [0,146][768,1184]
      (0) View [0,146][768,1184]
        (0) FrameLayout [0,146][768,1184]
          (0) FrameLayout [0,146][768,1184]
            (0) RelativeLayout [0,146][768,1
```

Node Detail

index	1
text	
resource-id	com.google.android.gm:id/search
class	android.widget.TextView
package	com.google.android.gm
content-desc	Search
checkable	false
checked	false
clickable	true
enabled	true
focusable	true
focused	false
scrollable	false
long-clickable	true
password	false

M-Aegis Architecture

- Per-Target Client App (TCA) Logic
  - Processes UI tree to determine a TCA's current UI state
  - Draw overlay for en/decryption
    - Editbox for message, etc.
    - 'Send' button
    - Display decrypted string for an encrypted message



Do you have time for chat? 4:03 PM

Let me know when you are available. 4:06 PM

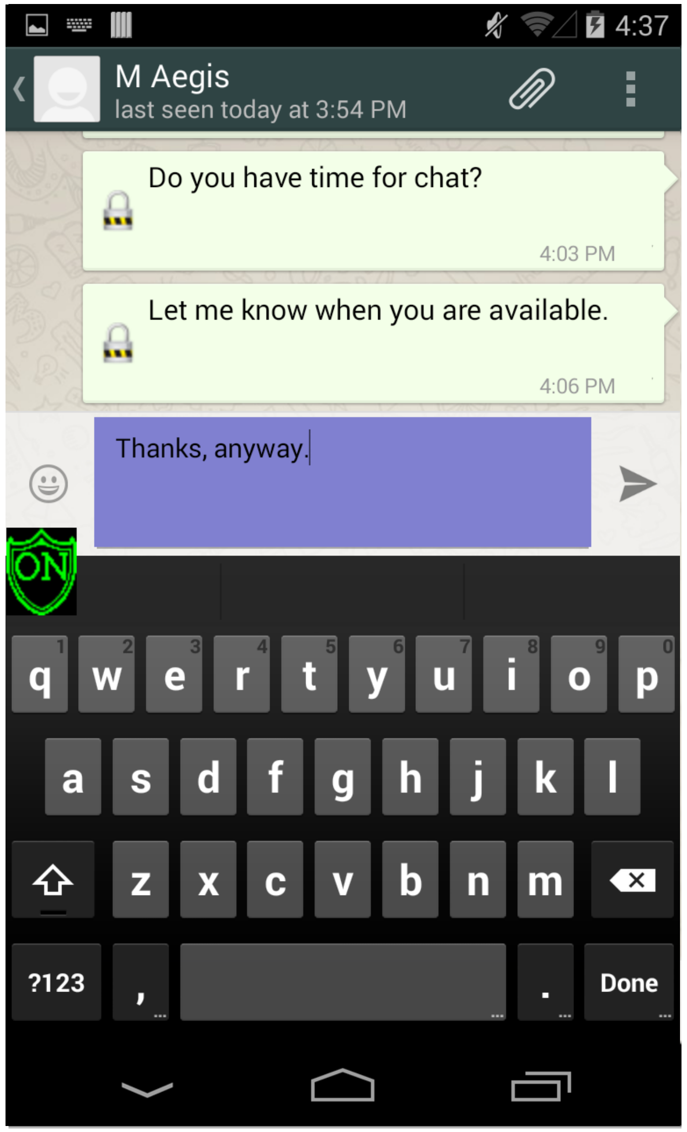
Thanks, anyway.

M-Aegis Architecture

- Searchable Encryption Scheme
  - Easily-Deployable Efficiently-Searchable Symmetric Encryption Scheme (EDESE)
  - Main idea – tag the encrypted text
  - Utilize bloom filter (BF) to “collect” keywords.
    - Problem: email providers don’t support BF tests.
    - Solution: cleverly encode BF in such a way that it is searchable by simple string matching.

M-Aegis WhatsApp Workflow

- 1. Do key exchange with a friend
- 2. On entering the messaging UI, TCA detects recipient information
  - Retrieve the correct key to use
- 3. TCA will detect encrypted messages, and decrypt them then display on the overlay
- 4. TCA will overlay editbox and send button and send encrypted message on clicking the button

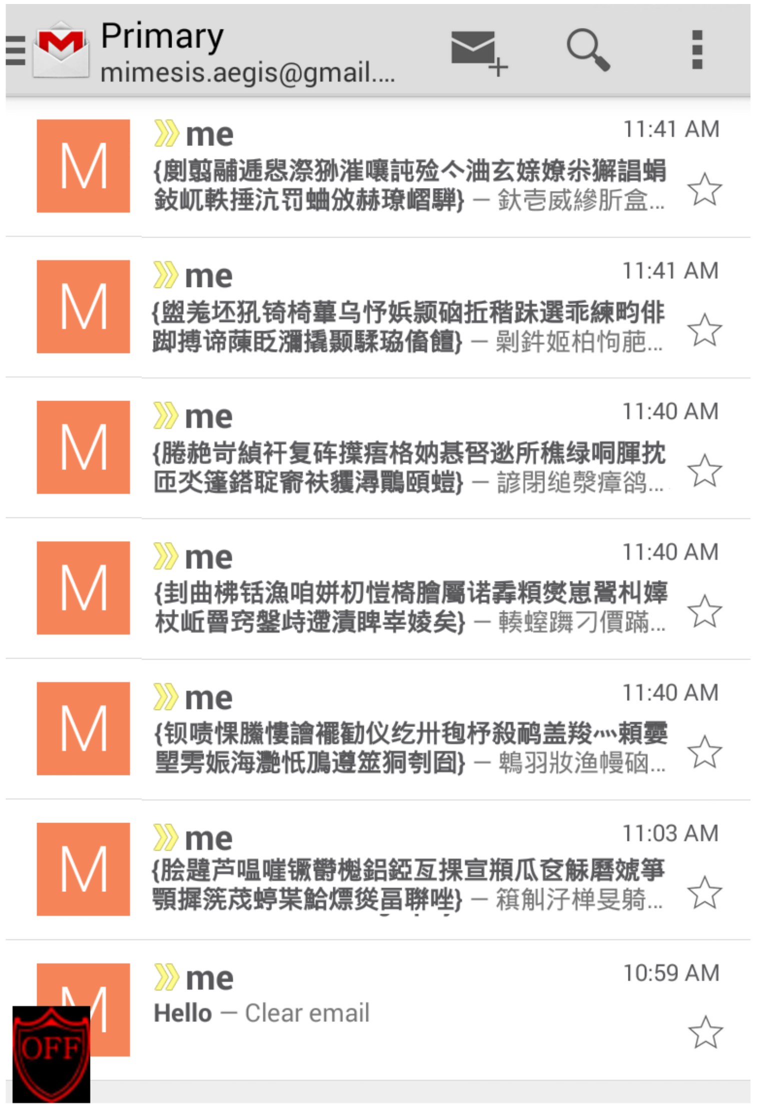

M Aegis
last seen today at 3:54 PM

Do you have time for chat?
4:03 PM

Let me know when you are available.
4:06 PM

Thanks, anyway.

M-Aegis Gmail Preview



Primary
mimesis.aegis@gmail....

me 11:41 AM
{劆翺䶵逓愳潹㹦潅嚷訰殓亽油玄婨嫽尜獬諿蝟鈹屼軼捶沆罚蚰敀赫璙嵧騨} – 鈦壱威縿肵盒...

me 11:41 AM
{盥羗坯犱锜椅蕐乌忬娦顥硇扸稭趎選乖練昀俳踋搏谛蔯眨瀰撬颢鞣瑡僪饄} – 剶鉼姬柏恂葩...

me 11:40 AM
{腱艴岢績衦复砟撲瘖格妠惎晵逖所樵绿哃腪抌匜炏篷鐯聇甯袂貜潯鷉頤螘} – 諺閉縋槃瘴鸹...

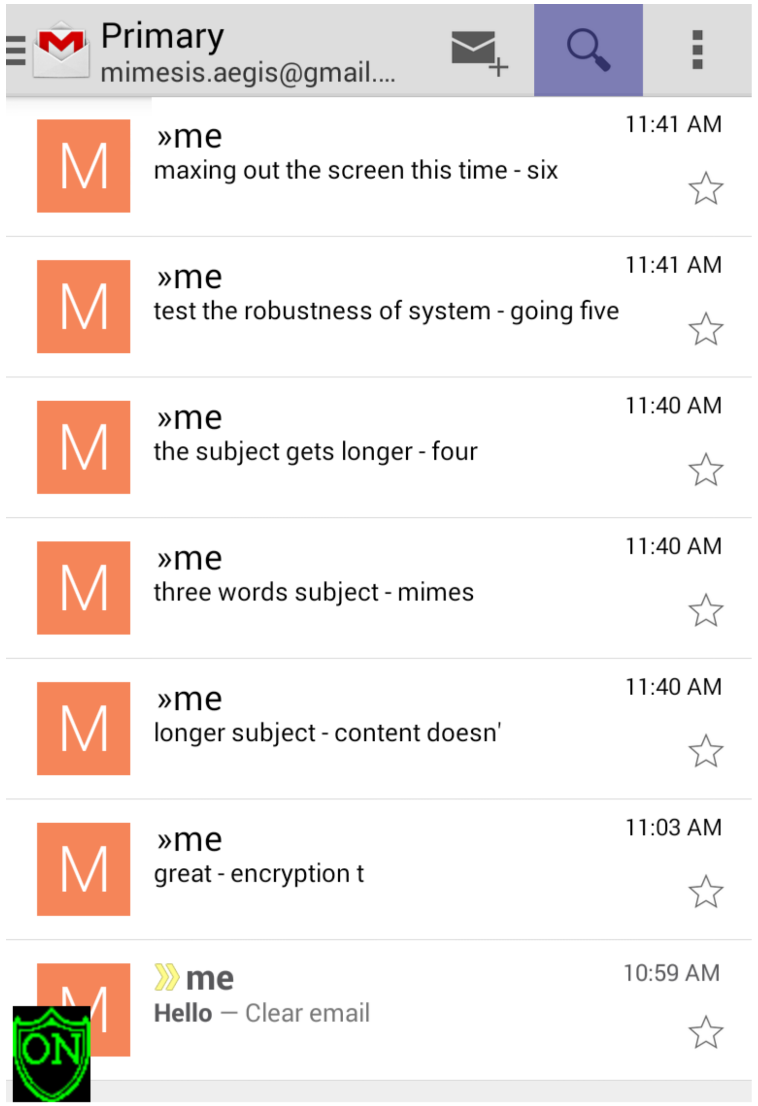
me 11:40 AM
{卦曲椖铦漁咱姘杒愷椅膾屬诺毳糗燓崽鬻杊嫴杖岴嚣窍鐢峙遻潰睥崒婈矣} – 輳蝰蹰刁價蹣...

me 11:40 AM
{钡啧慄臜慺諭襬勧仪纥卅皏杼殺鸸盖羧灬頼耍墅雳娠海灪怟鴄遵筮狪剨圄} – 鵏羽妝渔幔硇...

me 11:03 AM
{脍韙芦嗢嗺镢欝檓鋁鋕亙揲宣瓶瓜宸稣曆虢箏顎握筅茂蜳某紿熛篜畐聯唑} – 篞觓汿榸旻騎...

me 10:59 AM
Hello – Clear email

OFF



Primary
mimesis.aegis@gmail....

»me 11:41 AM
maxing out the screen this time - six

»me 11:41 AM
test the robustness of system - going five

»me 11:40 AM
the subject gets longer - four

»me 11:40 AM
three words subject - mimes

»me 11:40 AM
longer subject - content doesn'

»me 11:03 AM
great - encryption t

me 10:59 AM
Hello – Clear email

ON

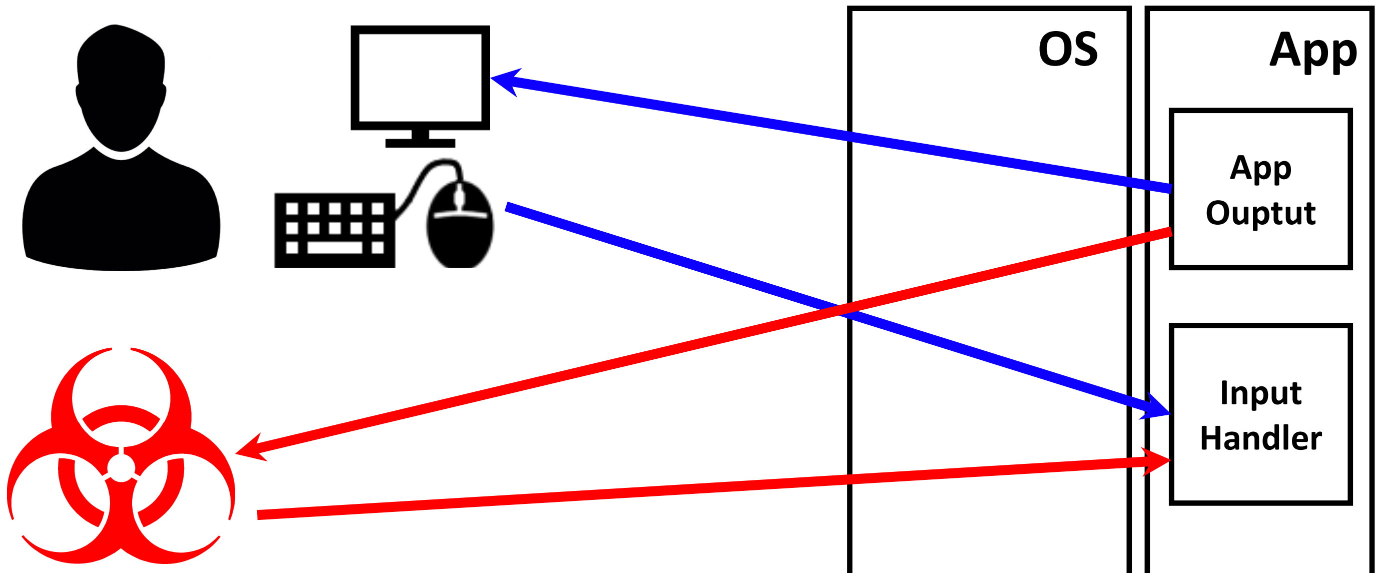
Performance Evaluations

- Experimental Setup:
  - Stock Android phone (LG Nexus 4)
    - Android 4.4.2 (Kit Kat, API Level 19)
- Preview Encrypted Email:
  - 76 ms to render plaintext on L-7.5
  - Well within expected response time (50 – 150 ms)
- Composing and Sending Encrypted Email:
  - Used Enron Email Dataset
  - With longest email:
    - 953 words, of which 362 are unique
    - 205 ms to encrypt, build the search index, and encode

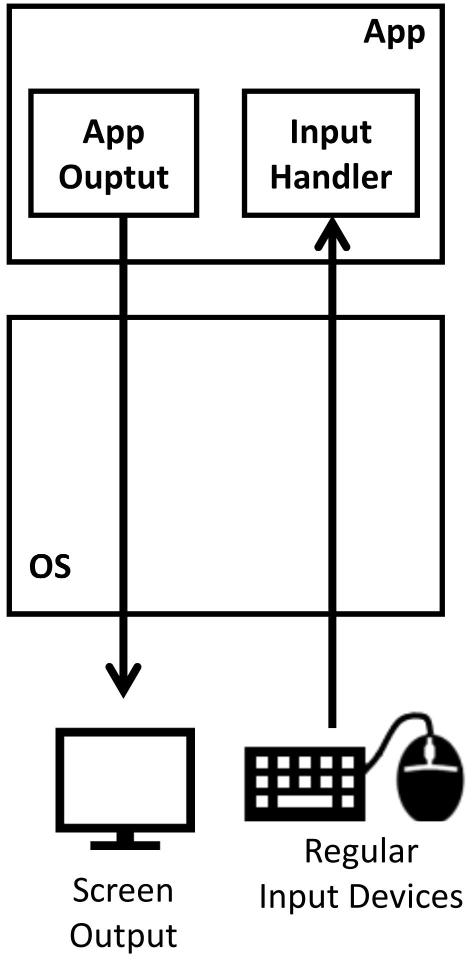
Limitations

- Social engineering attacks (phishing)
- Only handles text-based apps
- TCA-logic update is required if the app updated the UI

A11y Attacks: On the Importance of checking the Authenticity of User I/O



Traditional User I/O Paths in OS

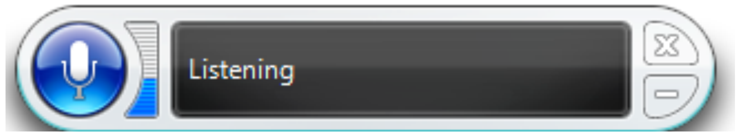


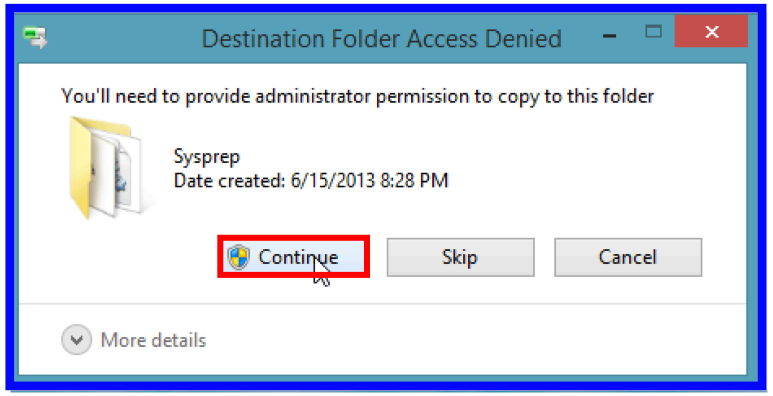
New User I/O Devices in OS – Accessibility (a11y)

- Voice commander
  - Receives user input from microphone
- Screen reader
  - Send UI output to a11y system as well as output display
- On-screen keyboard
  - Generates key clicks by software
- etc.

A11y Added New I/O Paths to OS

Click Continue!



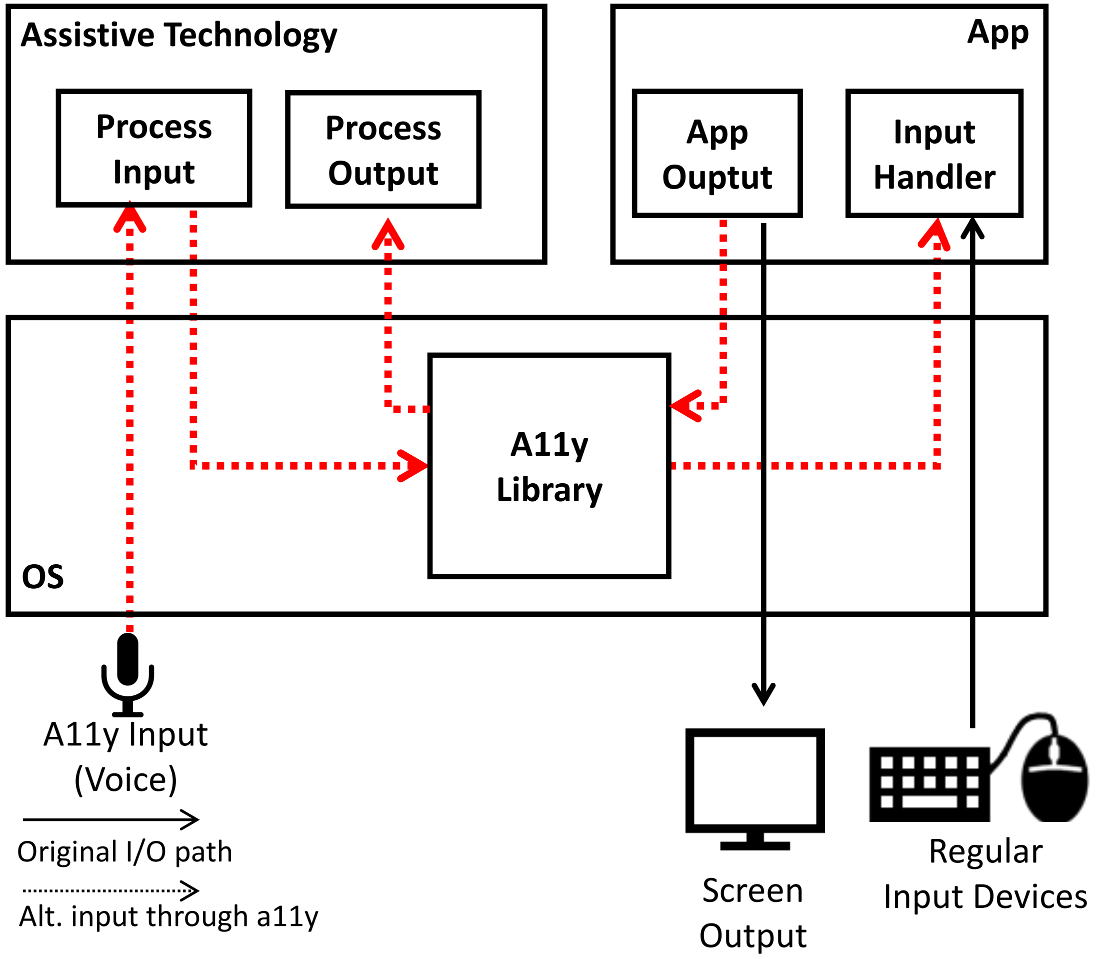

Destination Folder Access Denied

You'll need to provide administrator permission to copy to this folder

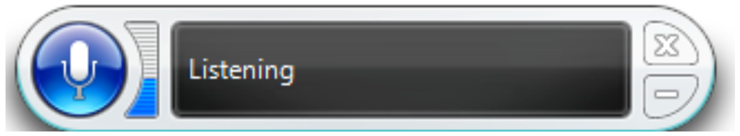
Sysprep
Date created: 6/15/2013 8:28 PM

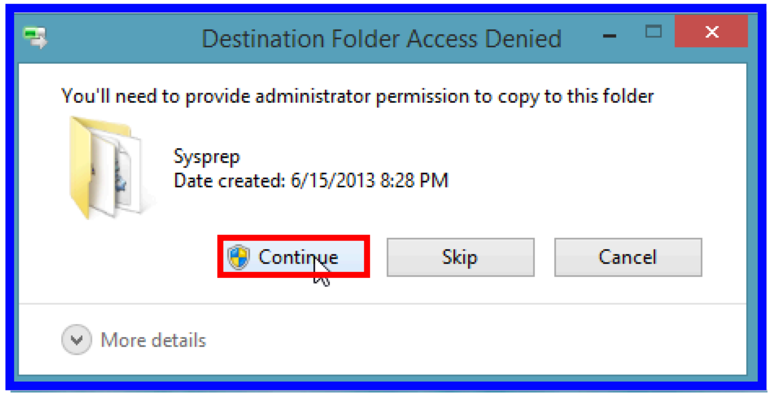
Continue Skip Cancel

More details



A Malware Can Attack A11y



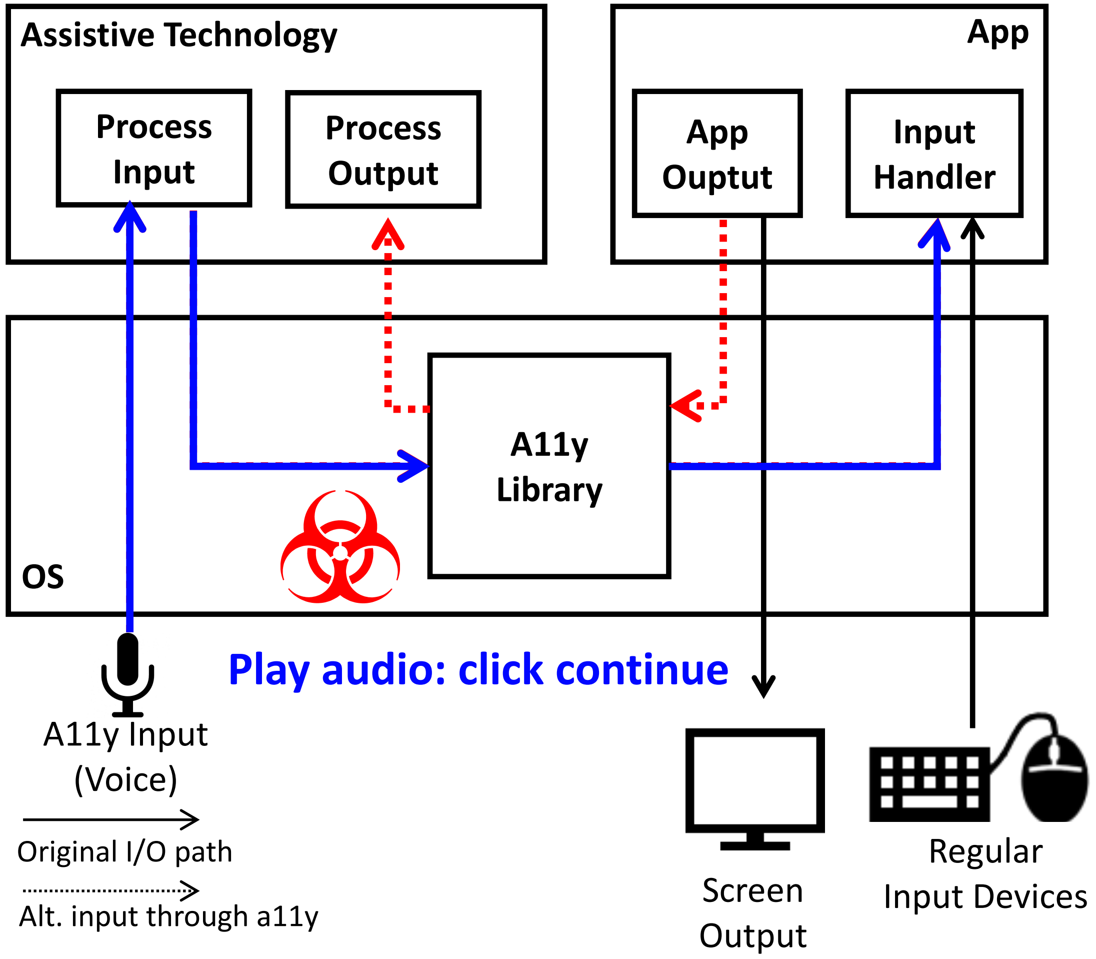

Destination Folder Access Denied

You'll need to provide administrator permission to copy to this folder

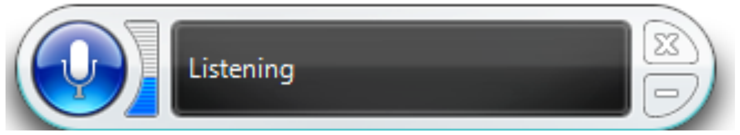
Sysprep
Date created: 6/15/2013 8:28 PM

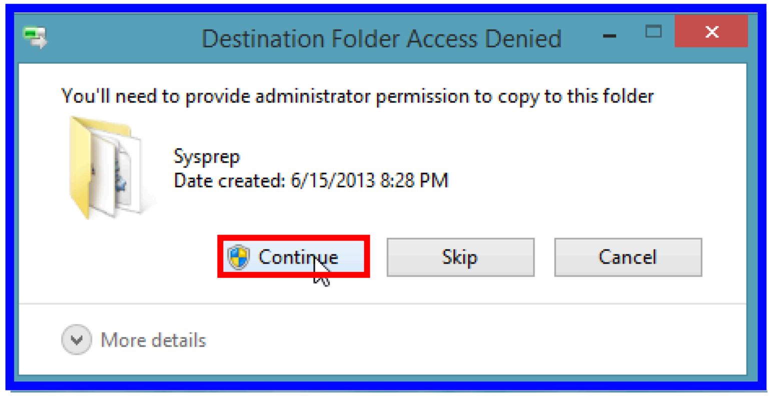
Continue | Skip | Cancel

More details



A Malware Can Directly Send Command




Destination Folder Access Denied

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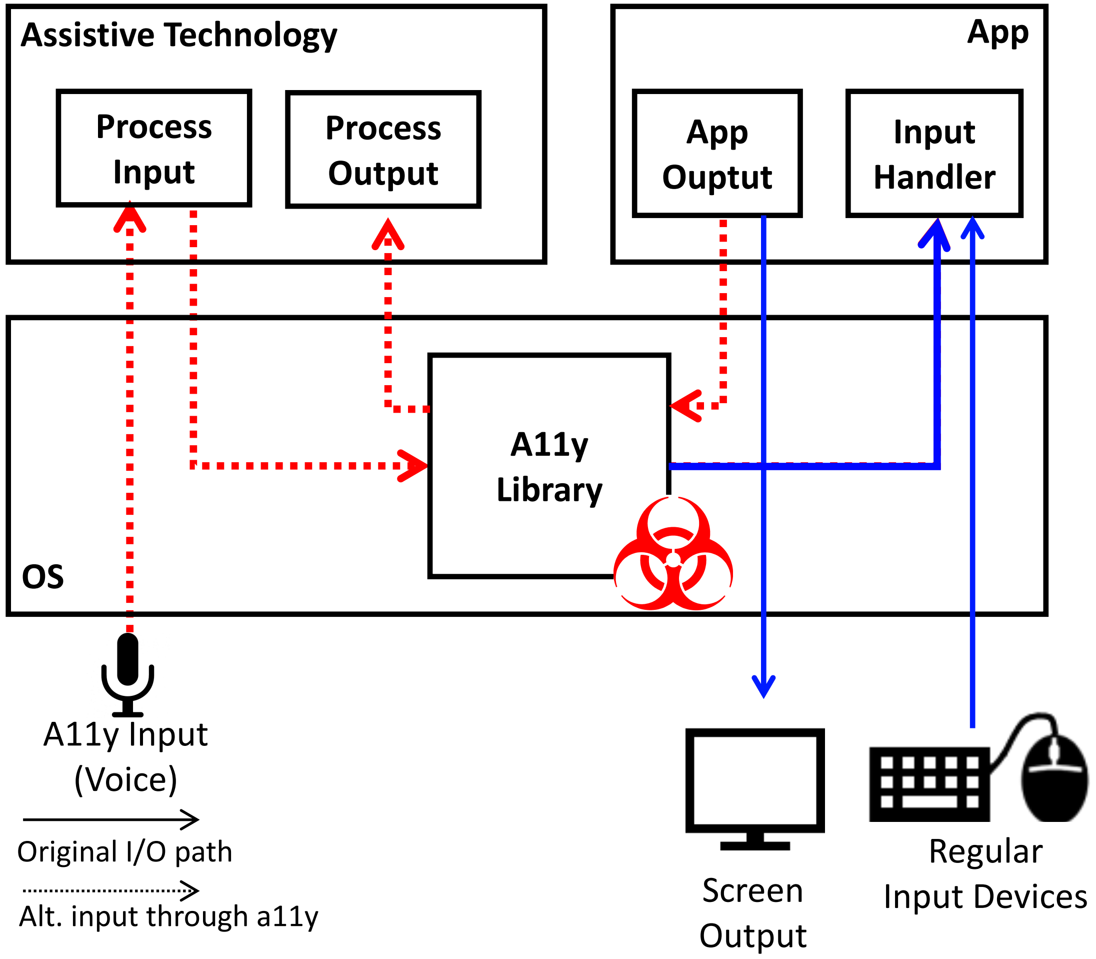
Continue Skip Cancel

More details



Security Implications of A11y

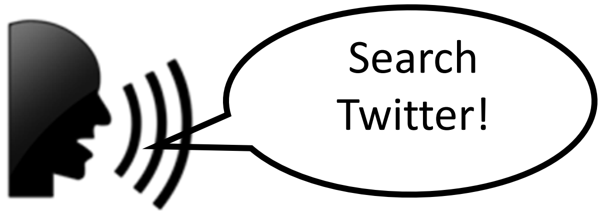
- Creates new I/O Paths
  - A11y allows **a program to send an input** event to the application
  - A11y allows **a program to read an output** of the other applications

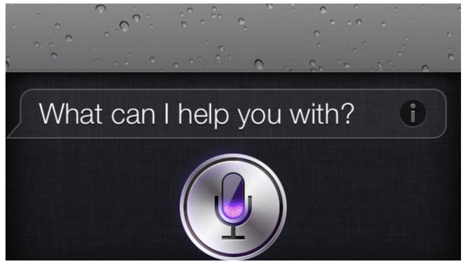
A (*malicious*) program can pretend as a user
if systems miss security checks on a11y inputs

Security Analysis for A11y

- Objective
  - Check OSes if they are secure under a11y attacks through new I/O path
- Method
  - Test security checks from the component
  - At assistive technology level (e.g., voice commander)
  - At OS level
  - At App level

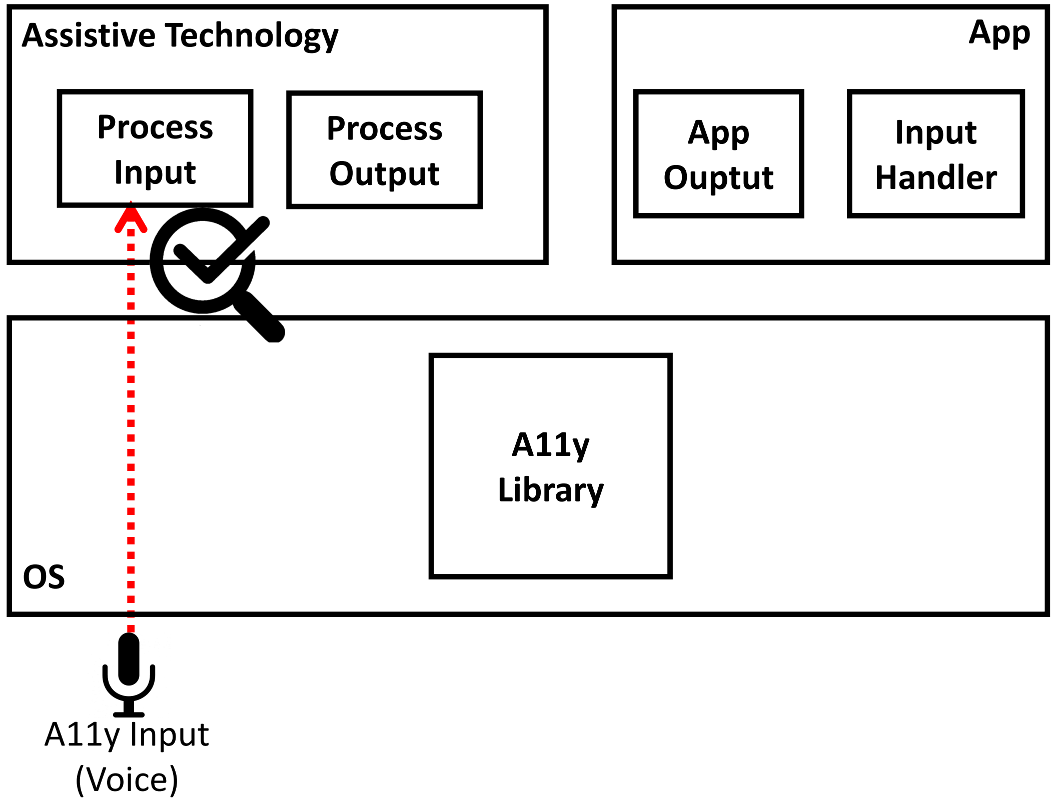
At Assistive Technology (AT) Level





Authenticate the input

- Is the voice from **real human**?
  - If not, machine can access it!
- Is the voice matched with **registered user**?
  - If not, any other human user can access it!



Attacks on Voice Commander

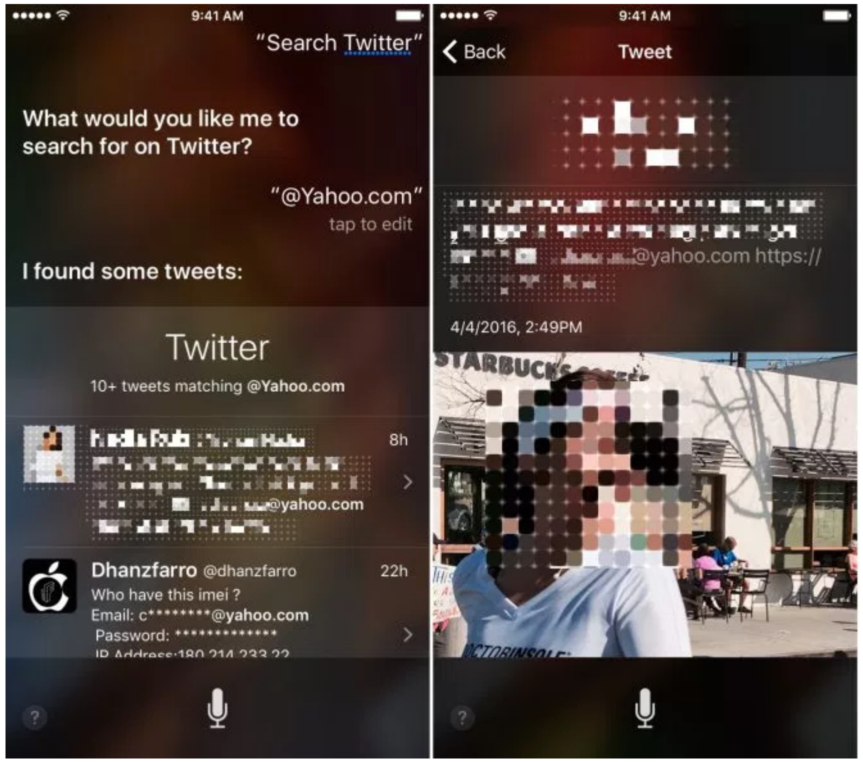
Siri's Lockscreen Bypass A Growing Privacy Issue For iOS Users

In less than 30 seconds, anyone with access to an Apple iPhone or iPad can extract a lot of personal data using Siri, Trend Micro says.

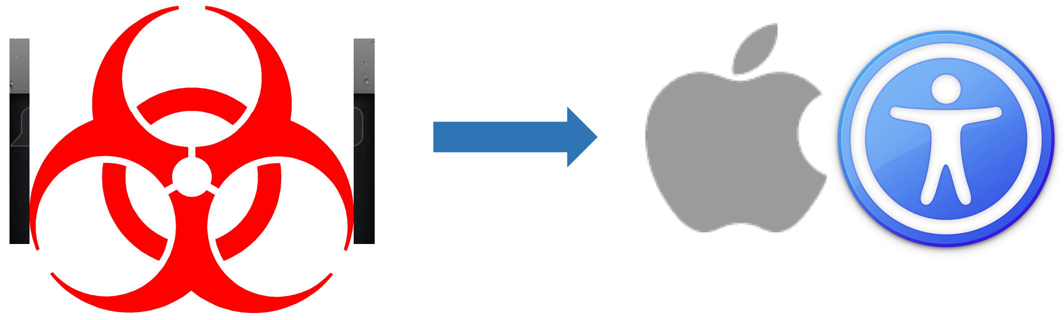
Security vendor Trend Micro has sounded the alarm once again on a continuing issue with Apple's Siri digital assistant that lets anyone with physical access to an iOS device to interact with it and easily extract data even if the device is locked.

In a blog post today, security researchers from the company said it takes just 30 seconds for someone to extract names, phone numbers, and calendar entries -- or even post to a connected social media account -- from a locked iOS device using simple voice commands.

"A locked device should not disclose the owner's identity and contact information, as well those of the owner's friends, family, and contacts," the researchers wrote. "Siri bypasses this and provides detailed information and other functions on a locked mobile device."



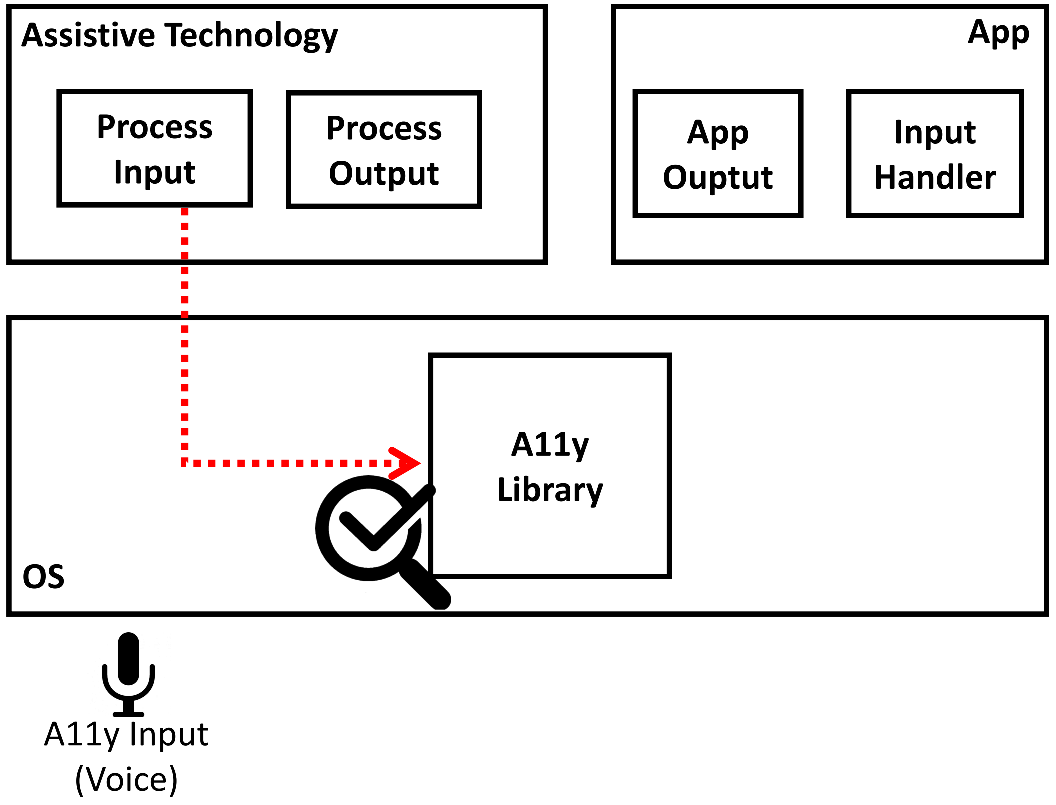
At OS Level



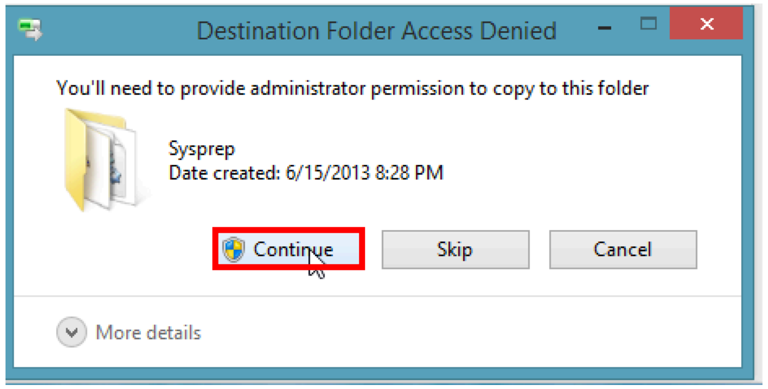
Access control is required

Assistive technology allowed to access a11y?

If not, any program (possibly malware) can access it!



At Application Level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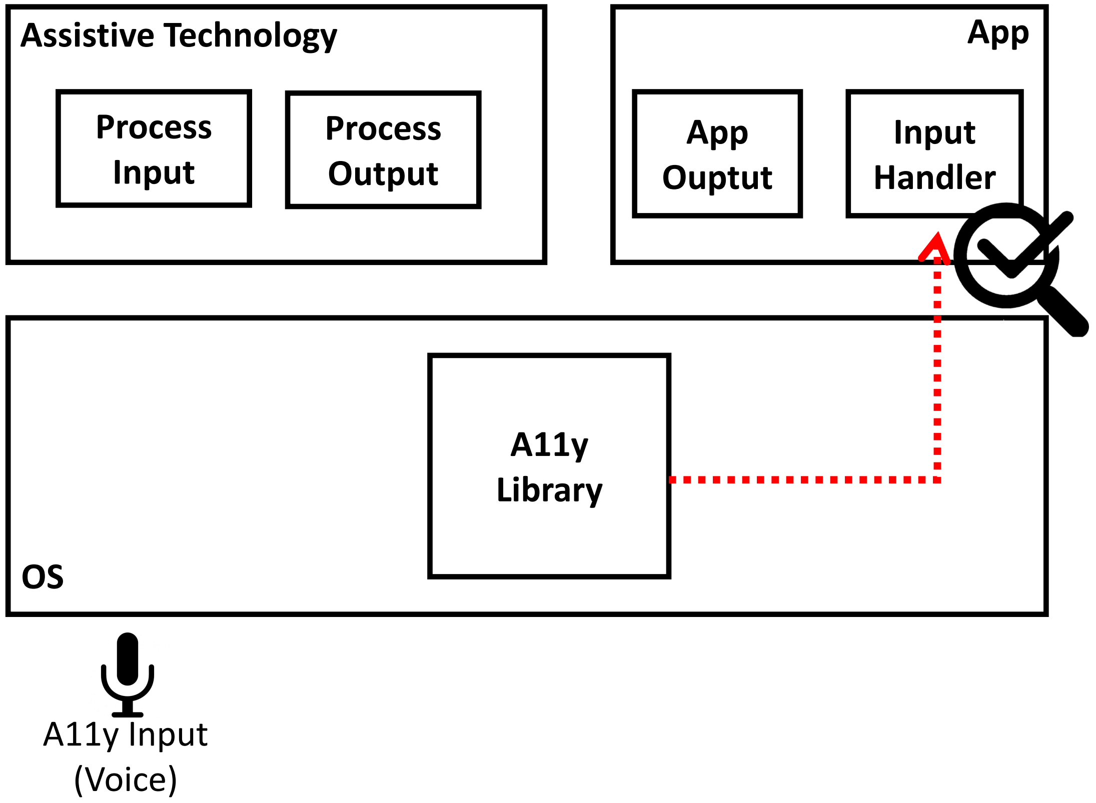
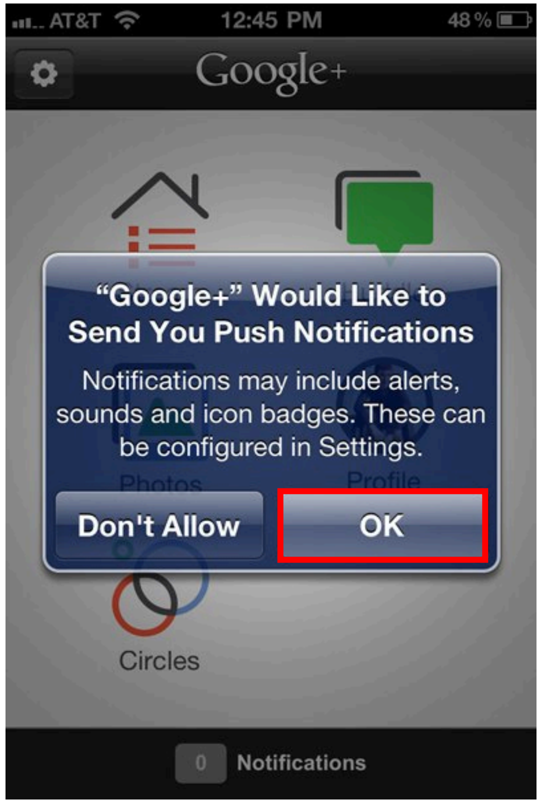


Distinguish User input from A11y Input

Do not allow to perform security sensitive UI!

Permission Views in iOS

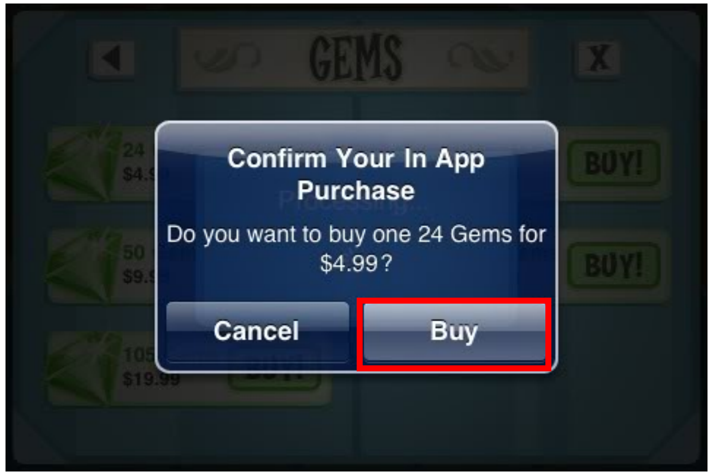


AT&T 12:45 PM 48 %

Google+

"Google+" Would Like to Send You Push Notifications

Notifications may include alerts, sounds and icon badges. These can be configured in Settings.



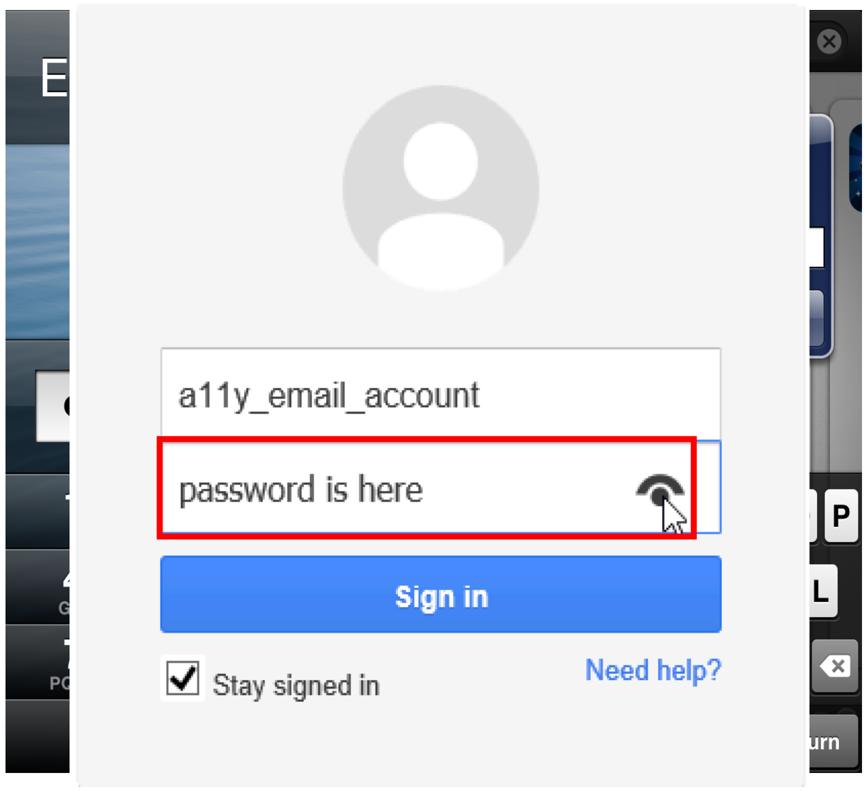
Confirm Your In App Purchase

Do you want to buy one 24 Gems for $4.99?

A malicious app can click this!

A11y Output Have a Conflict with System Features

- Visual feedback as accessibility
  - **No tactile feedback** in touch-screen devices
  - To reduce *typo*, OS provides visual feedback
  - Assumes **only user** can see it
  - Existing feature breaks its security
    - Screenshot!
    - iOS6: Private API allows screenshot
    - Windows: no restriction at all
    - Android: screen recording permission



Attacks on Missed Checkpoints

- We found 12 new vulnerable points
  - Windows (3)
    - 2 Privilege escalation, 1 password leak
  - Linux (2)
    - Bypassing process boundary, password leak
  - iOS (4)
    - Bypassing sandbox and authentication
    - Privilege escalation, Password leak
  - Android (3)
    - Bypassing sandbox and authentication
    - password leak

No Authentication for Alternative Input

- Any user, or a program can send voice to Siri

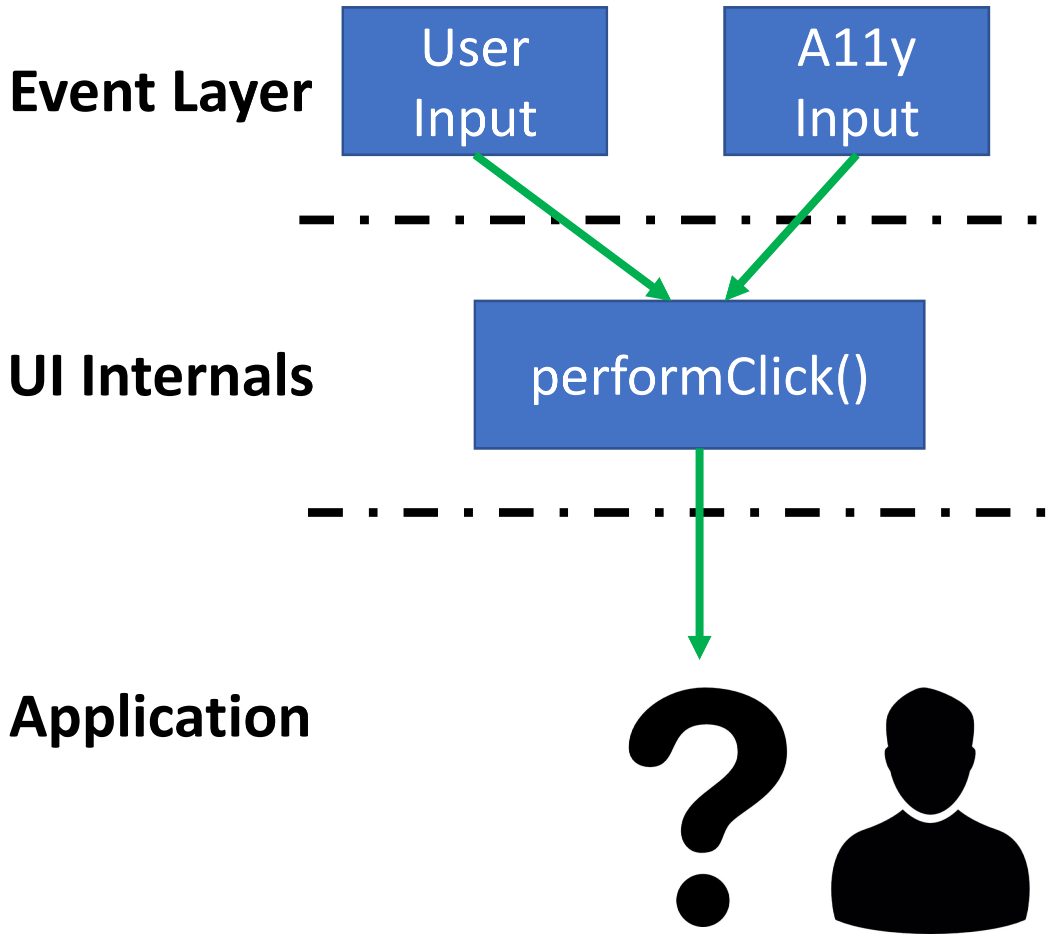
- Simple authentication is not enough
  - Liveness check
  - Challenge-response

- Vendors cannot ignore practical issues
  - Computational power
  - Power consumption
  - etc.

Weak Access Control on A11y Libraries

- Windows: None
- Ubuntu: None
- OS X : None
- iOS 6 : None
- Android: **User settings**

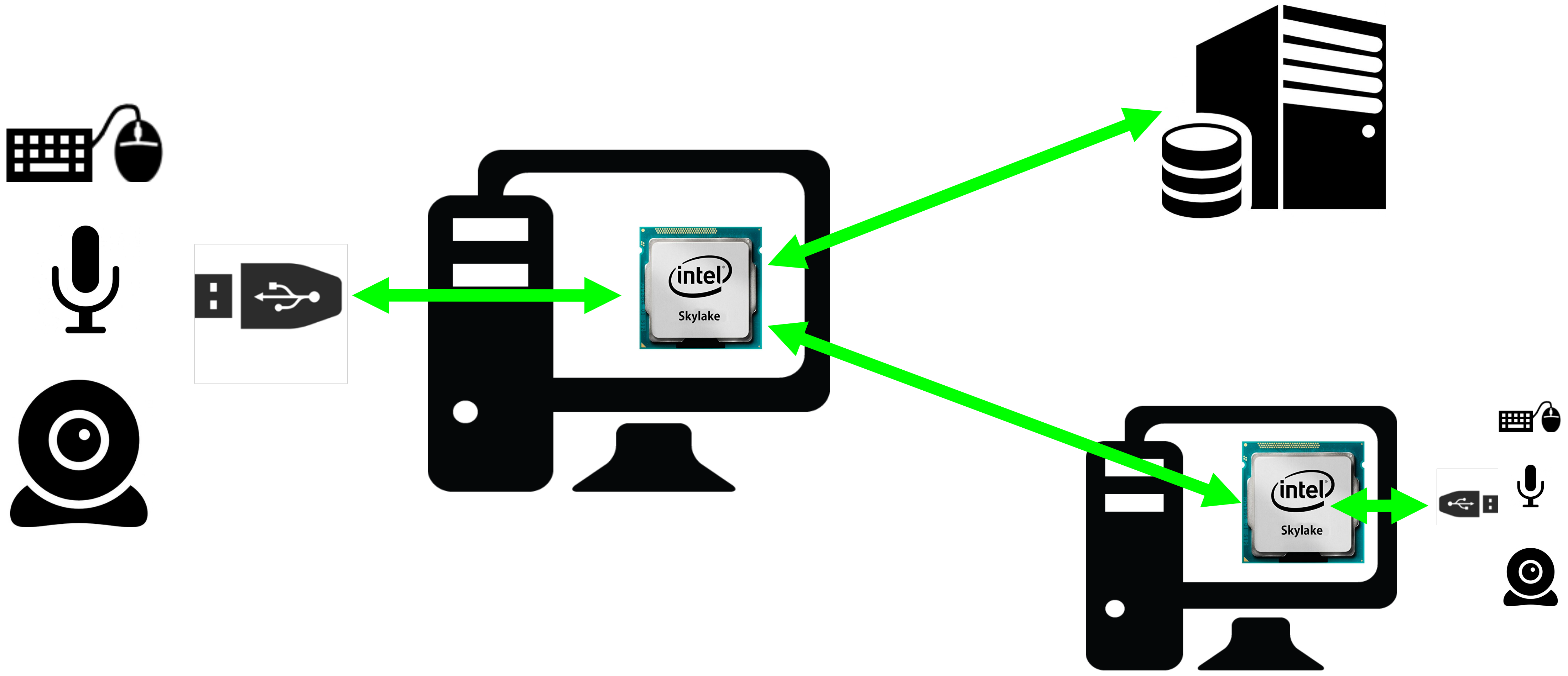
Compatibility Makes the Confusion



Recommendations for A11y

- Apply access control on a11y library
- Provide mechanism to distinguish a11y I/O from the real I/O requests
- For the security sensitive UIs, get input with proper authentication.

Bringing Assurance of User I/O in Intel SGX



Motivation & Problem

- Intel SGX
  - Provides a trusted execution environment only with hardware TCB
  - Security of an enclave is guaranteed even under the untrusted OS
- Challenges: SGX does not have any secure user I/O path
  - All I/O event must be handled by the untrusted OS
  - Most of existing works protect I/O through encryption
    - Haven, VC3, Ryoan, SGX-TOR, etc.
  - SGX-IO [CODASPY '17]
    - Requires a trusted hypervisor

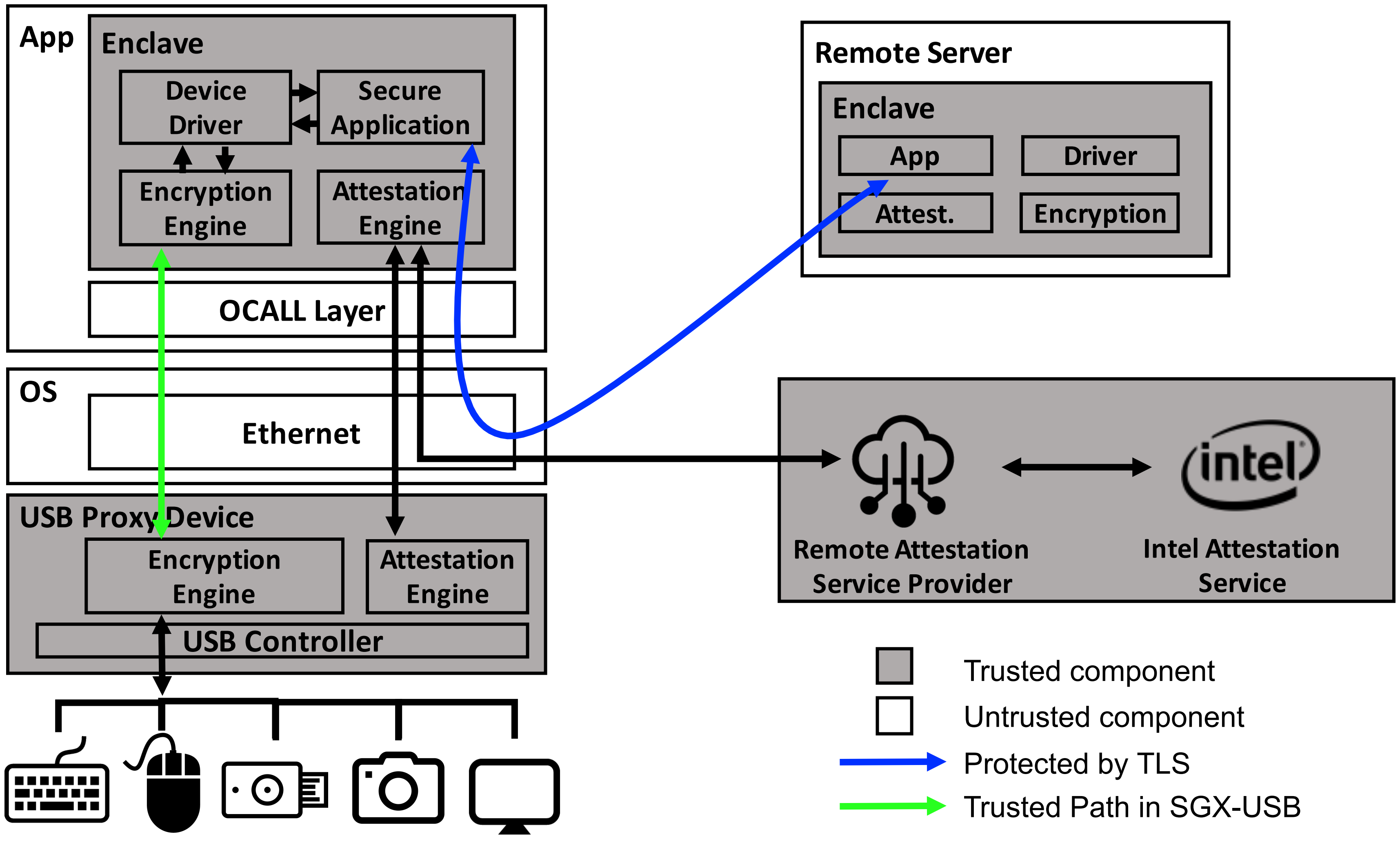
SGX-USB Overview

- Goal
  - Establish a trusted channel between a USB port and an enclave program to securely support the USB device I/O in an enclave
- Place a trusted hardware at the USB port (USB Proxy Device)
  - Authenticates with an enclave (remote attestation)
  - Delivers USB packet through the secure communication channel
- Enclave program
  - Interprets USB packets (driver)
  - Processes I/O at the user-level

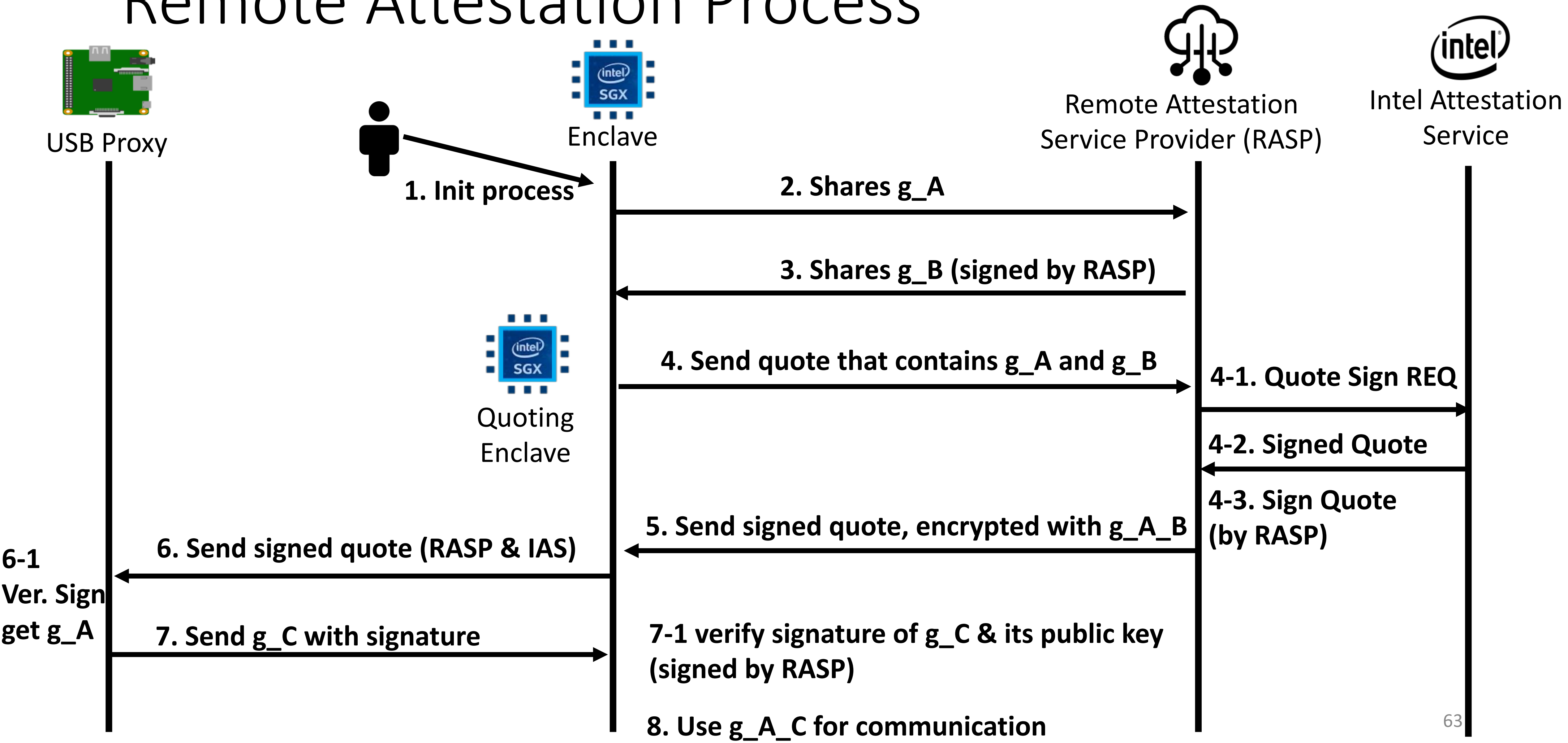
Threat Model

- Trust
  - The processor
  - The application that runs in an enclave
  - The remote attestation infrastructure
  - Building blocks for USB proxy device
  - Two public keys – from Intel and from Service Provider
- Do not trust
  - Do not trust OS and other applications
- Attackers do not have physical access to the devices

Architecture

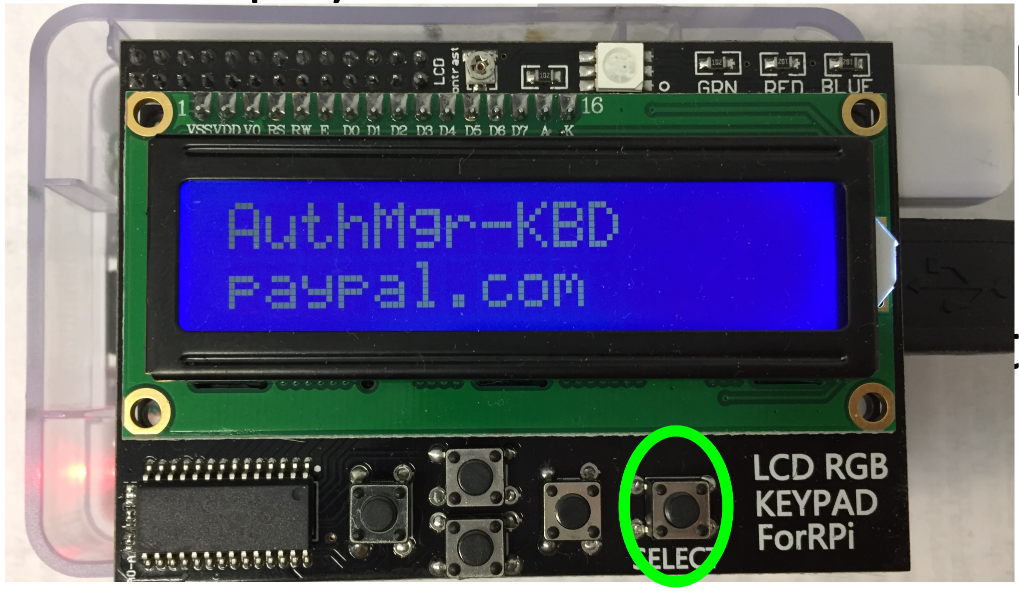


Remote Attestation Process


USB Proxy
Enclave
Remote Attestation Service Provider (RASP)
Intel Attestation Service
1. Init process
2. Shares g_A
3. Shares g_B (signed by RASP)
Quoting Enclave
4. Send quote that contains g_A and g_B
4-1. Quote Sign REQ
4-2. Signed Quote
4-3. Sign Quote (by RASP)
5. Send signed quote, encrypted with g_A_B
6. Send signed quote (RASP & IAS)
6-1 Ver. Sign get g_A
7. Send g_C with signature
7-1 verify signature of g_C & its public key (signed by RASP)
8. Use g_A_C for communication

A User’s Workflow

- If user wants to communicate with AuthMgr, then
  - Initiates RA process
  - The enclave authenticates with the RASP
  - USB Proxy Device authenticates with the enclave (shared g_A_C)
  - Display authentication information



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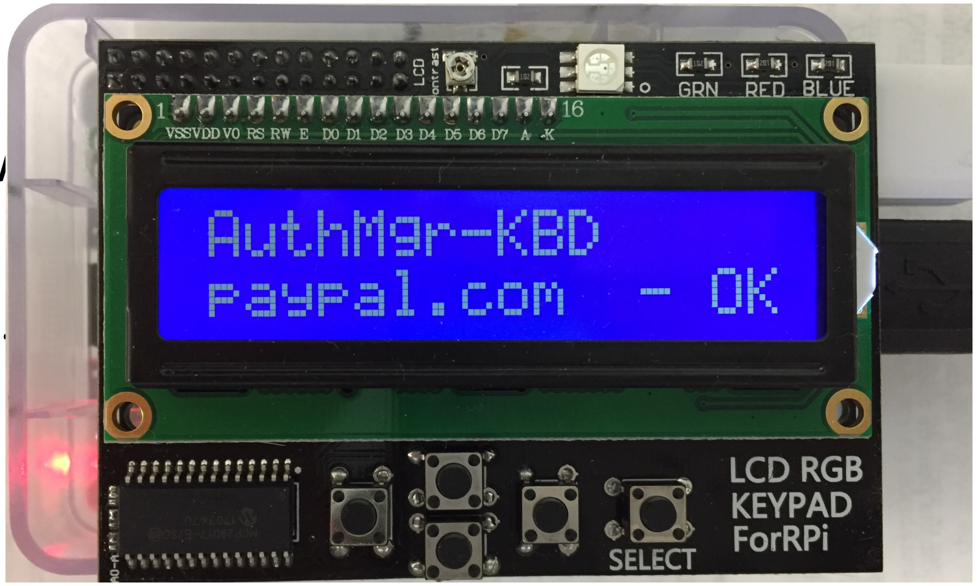
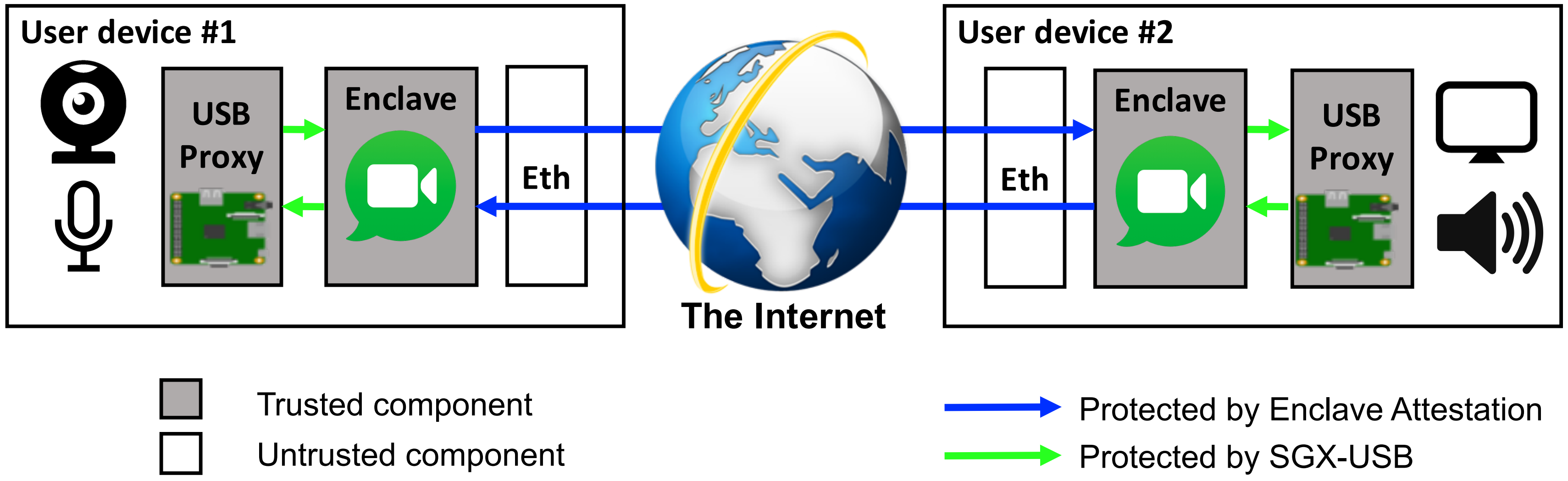


Use Cases

- Password manager & 2-factor authentication
  - User types passwords, and it only delivered to an enclave program
  - The program in enclave gets cookie and delivers the cookie to the application
- Secure video chat
  - Camera, microphone, display, speaker, etc.



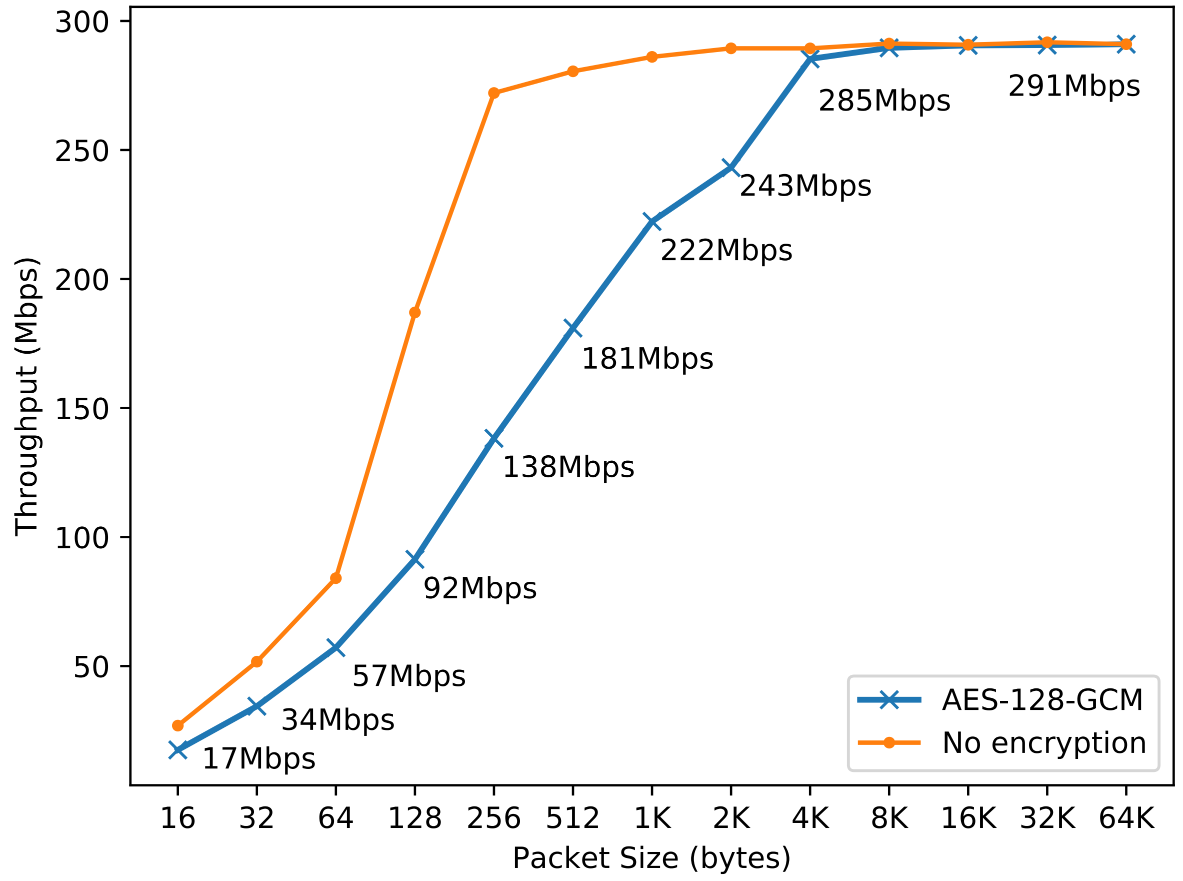
Implementation

- Prototype of SGX-USB
  - AuthMgr: get password input from a keyboard
  - Raspberry Pi 3 for USB Proxy Device
  - Implemented USB HID driver for keyboard in enclave
  - The RASP server

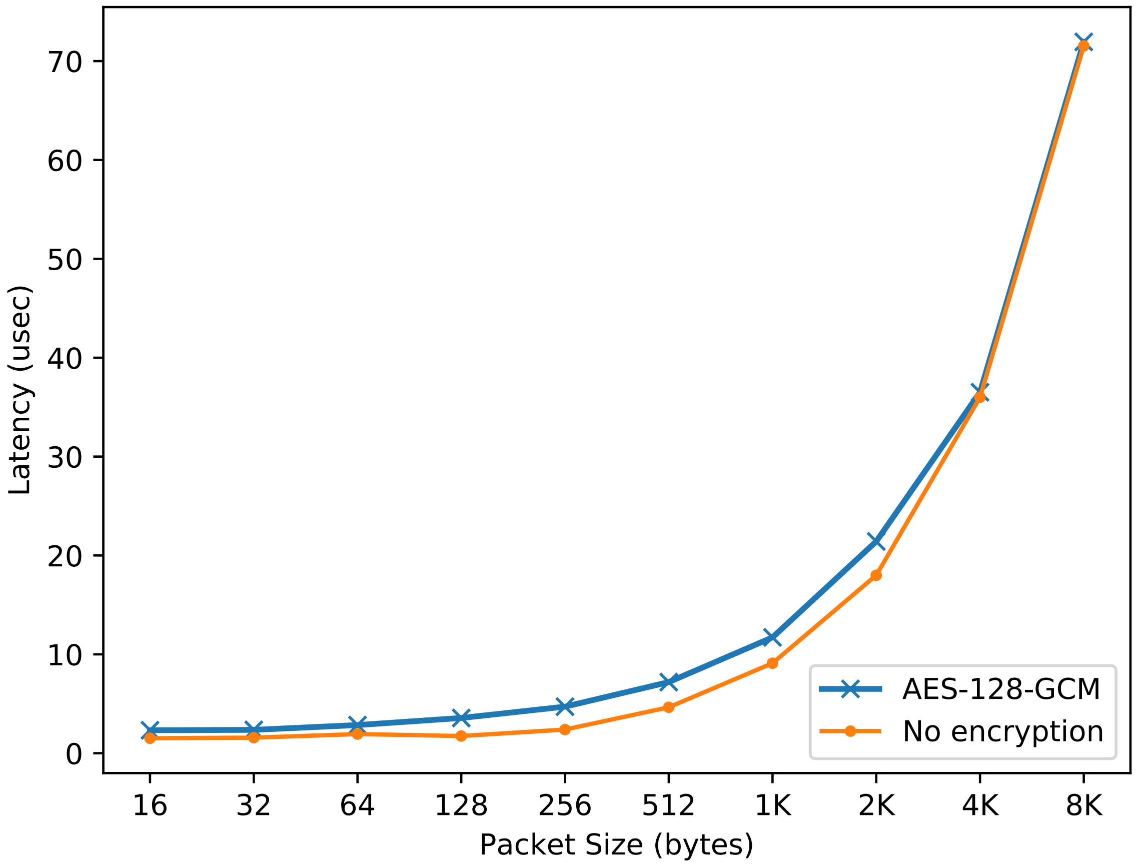
- ~ 4700 lines of C++ code

Evaluations

- Throughput



- Latency



Discussions

- General I/O support
  - All USB devices. Possibly support devices through RDMA
- Feasibility of hardware implementation
  - Required logics: USB Host, Networking, and Crypto (AES & ECHDE)
  - Small firmware can drive the logics
- Availability
  - Inherent limitation of Intel SGX

Conclusion

- Building Trust in the User I/O in Computer Systems
- Integrity
  - Gyrus: authorizing outgoing network traffic using user input data
- Confidentiality
  - M-aegis: provide end-to-end encryption of user input/output by implementing encryption layer on top of the UI layer
- Authenticity
  - A11y attack: pointed out security problems caused by missing checks for the source of user input and the destination of system output
- Assurance
  - SGX-USB: establishing a secure channel between a USB device and an enclave to provide integrity, confidentiality, and authenticity of user input