DIGITAL FORENSIC RESEARCH CONFERENCE

Digital Forensic Practices and Methodologies for AI Speaker Ecosystems

By

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Digital Forensic Practices and Methodologies for AI Speaker Ecosystems

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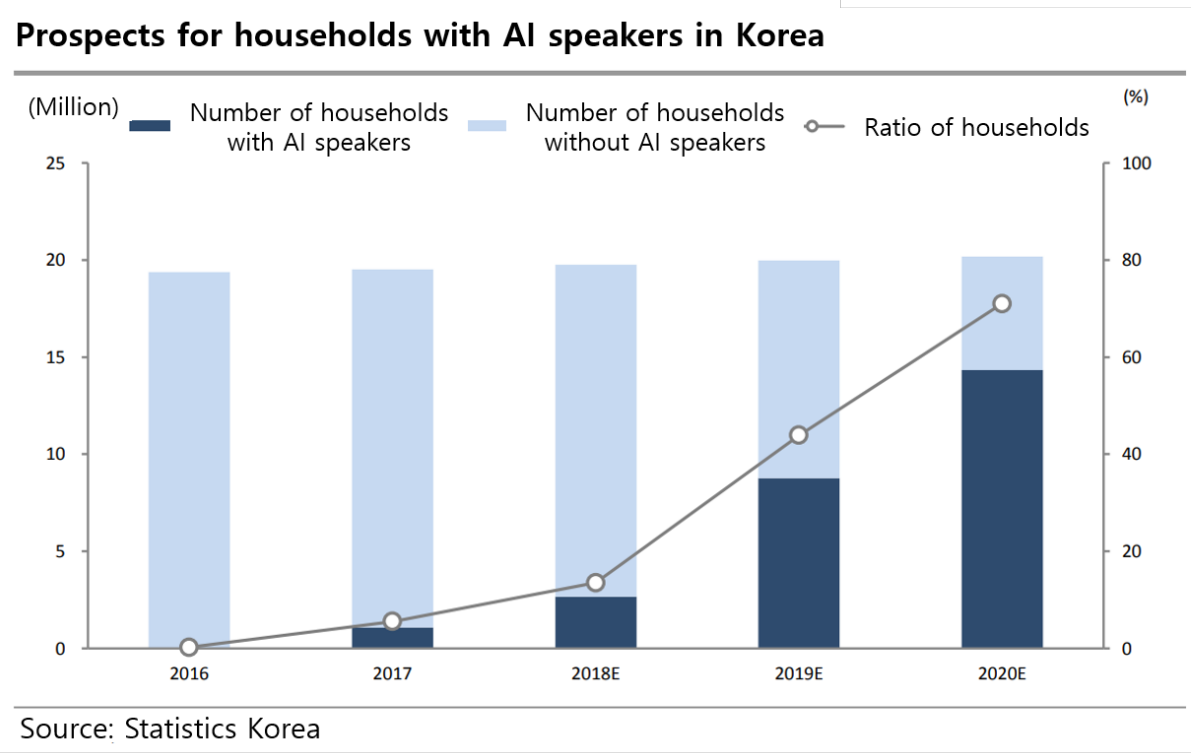
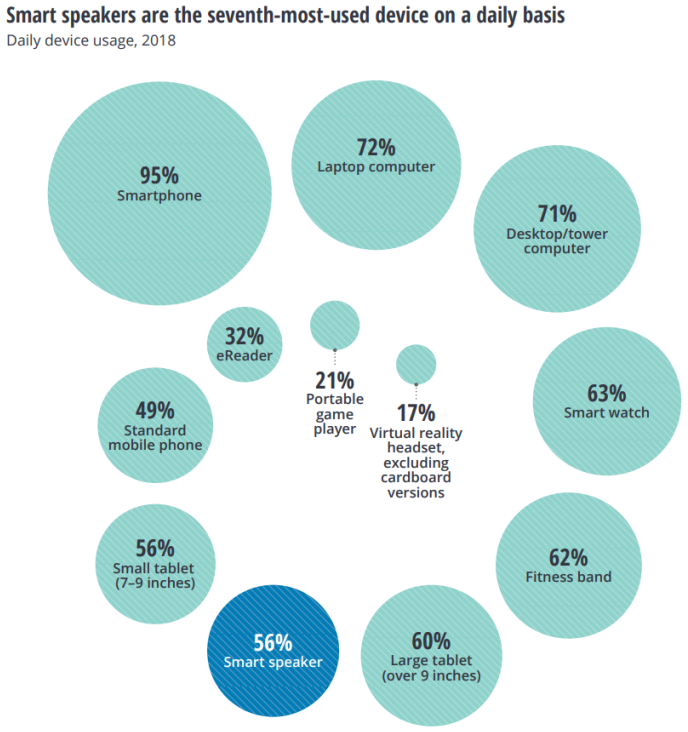
Motivation

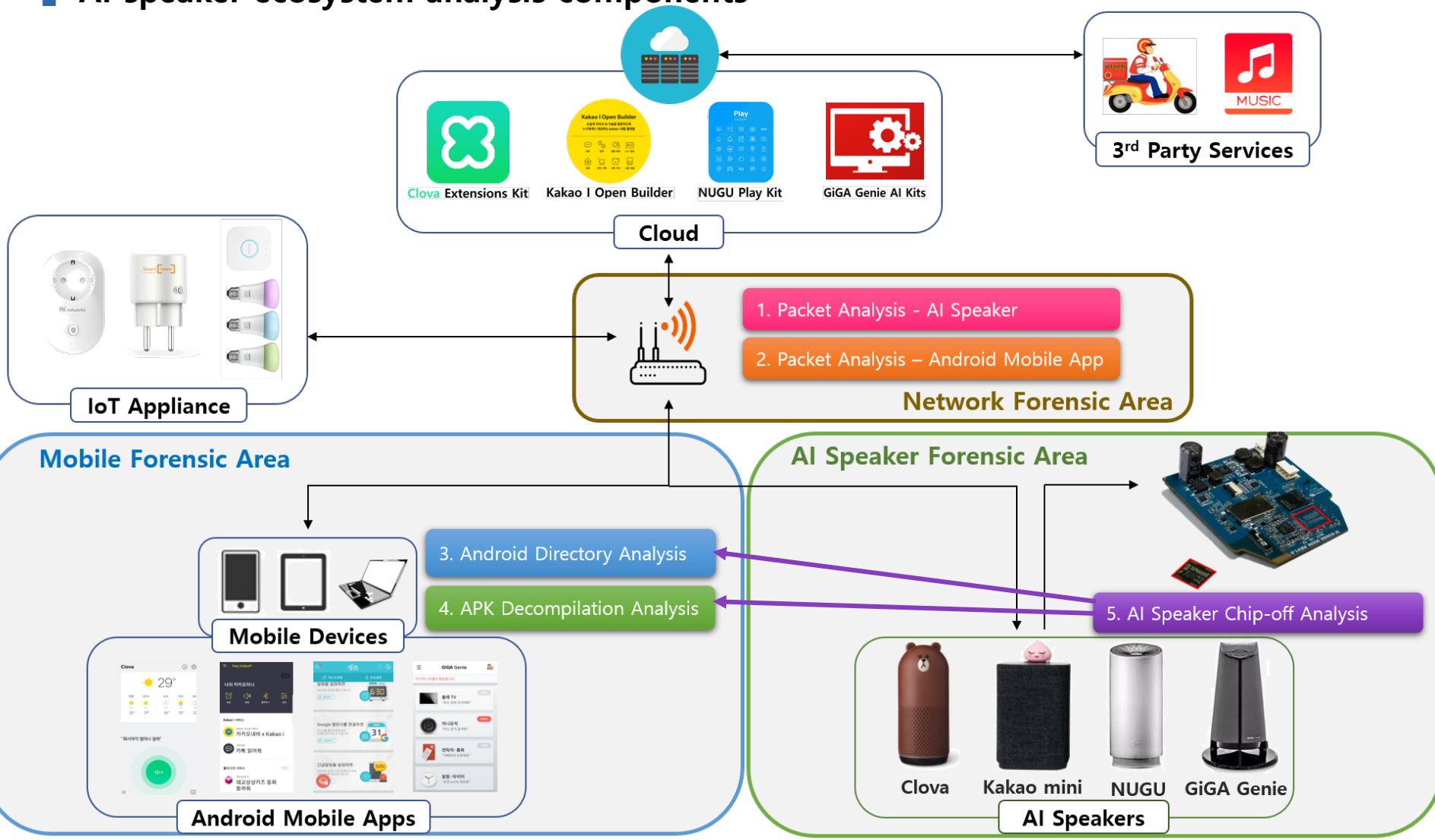
- [2018] U.S. AI speaker owners rose 39.8% to reach 66.4 million with total smart speakers in use rising to 133 million
- [2018] South Korea AI speaker owners rose over 900% to reach 1 million





Methodologies

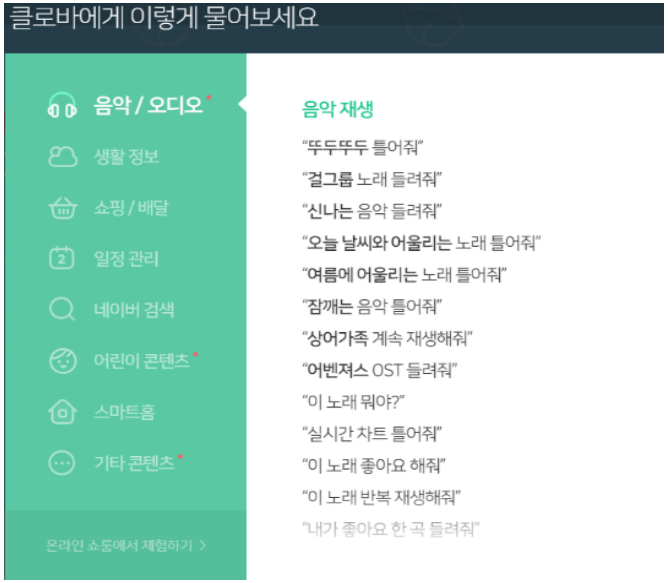
AI speaker ecosystem analysis components



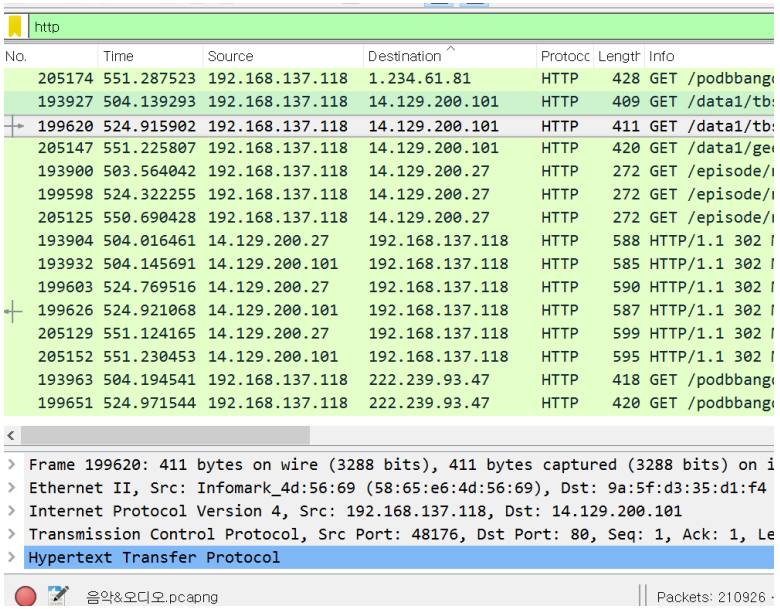
Methodologies
S01: Packet Analysis – AI Speaker

Data Collection and Analysis Methods

- **Proxy setting of speaker device impossible → Use Wireshark for packet sniffing**
  - HTTPS encrypted packets can not be analyzed, only HTTP traffic is analyzed
- **User Manual-based data collection**
  - Follow the instruction manual provided on the homepage to voice command and collect data with Wireshark tool
  - Capture the initial sequence between AI Speaker ↔ Android Mobile



Clova User Manual

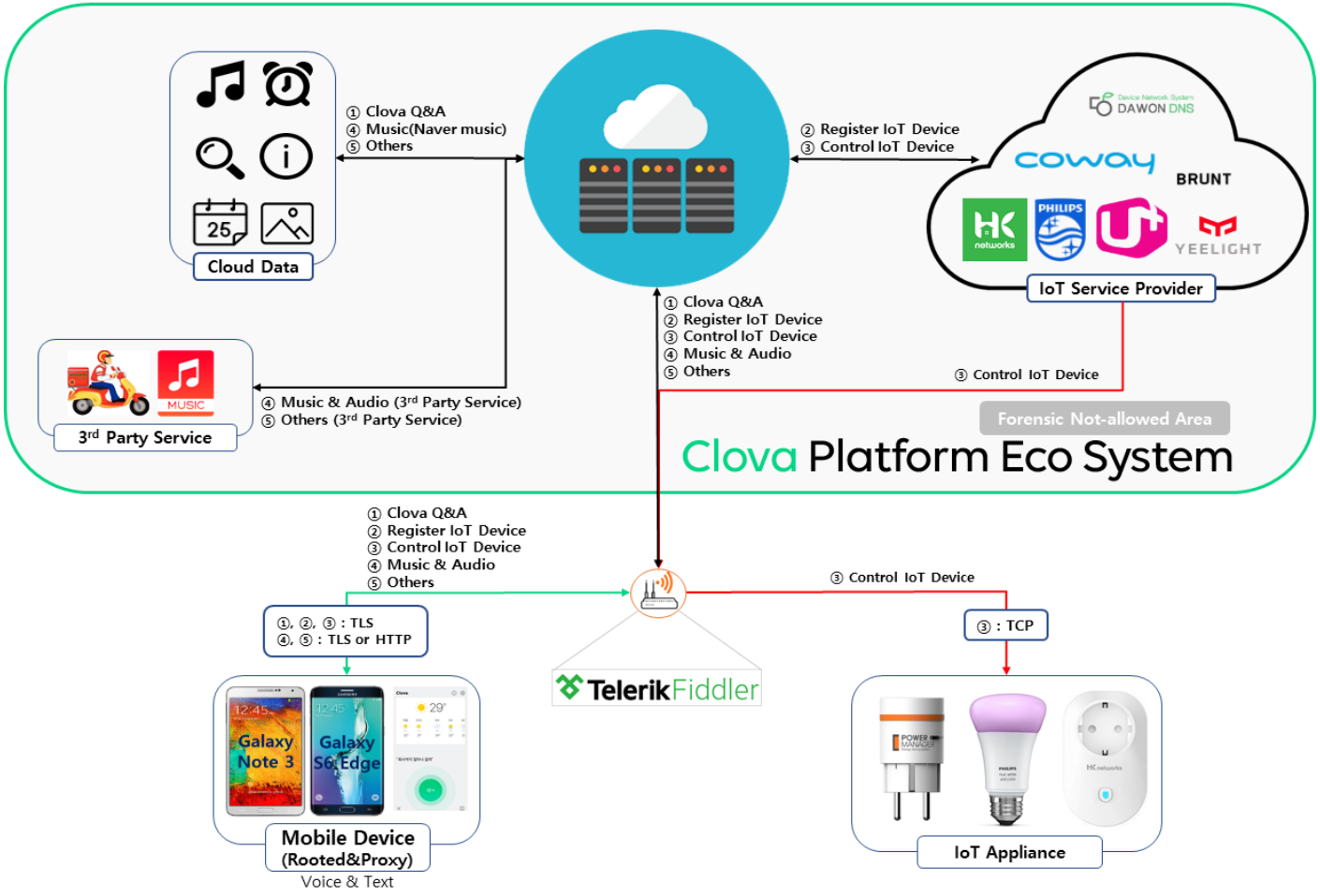


Wireshark HTTP Packet

Methodologies
S02: Packet Analysis – Android Application

Web Proxy Debugging – Fiddler

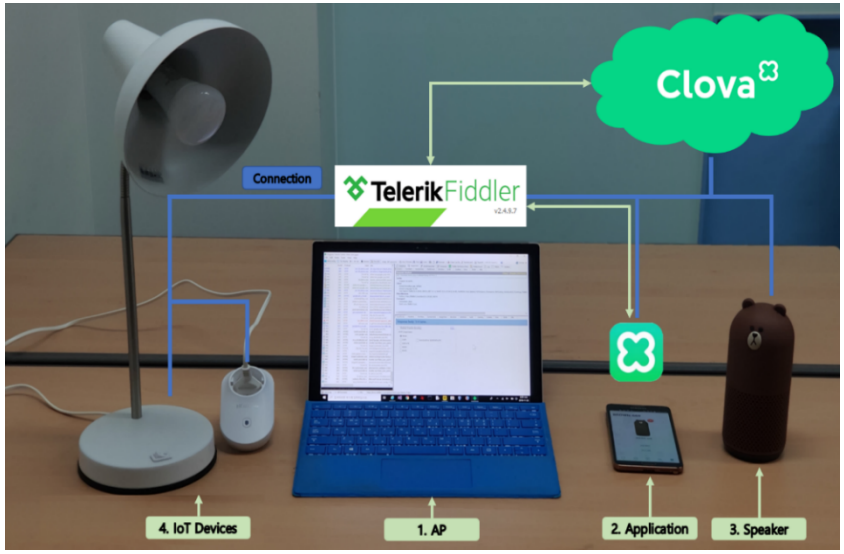
- Using MITM to see inside of HTTPS packet

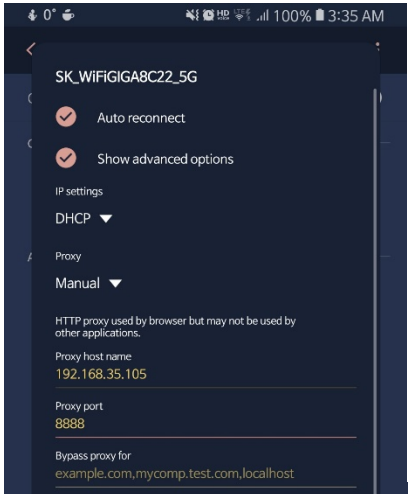


Methodologies
S02: Packet Analysis – Android Application

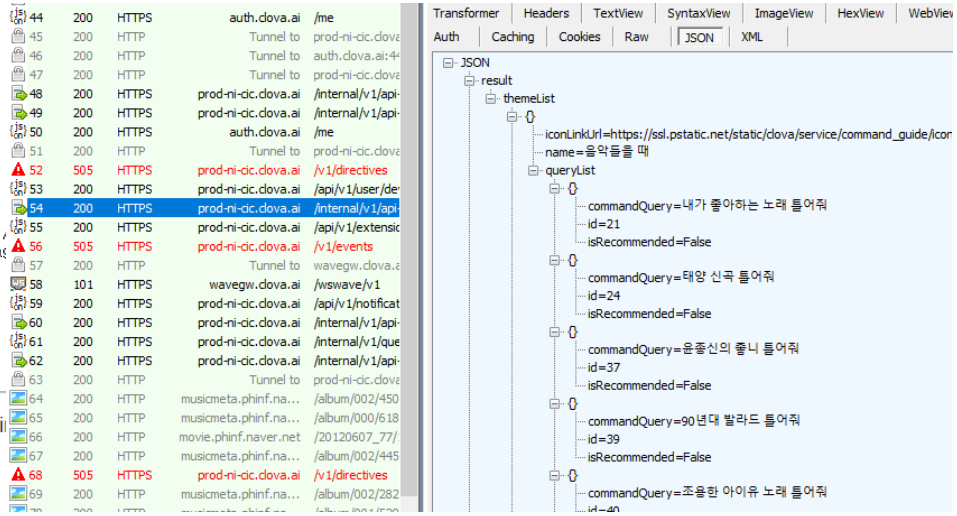
Data Collection and Analysis Methods

- **Web proxy tool Fiddler can analyze HTTPS (install Fiddler's Certificate on smartphone)**
- **User Manual-based data collection**
- **Analysis of domain-specific roles and cloud structure**
  - Comparison with AI speaker(Wireshark)
  - List up all exposed domains



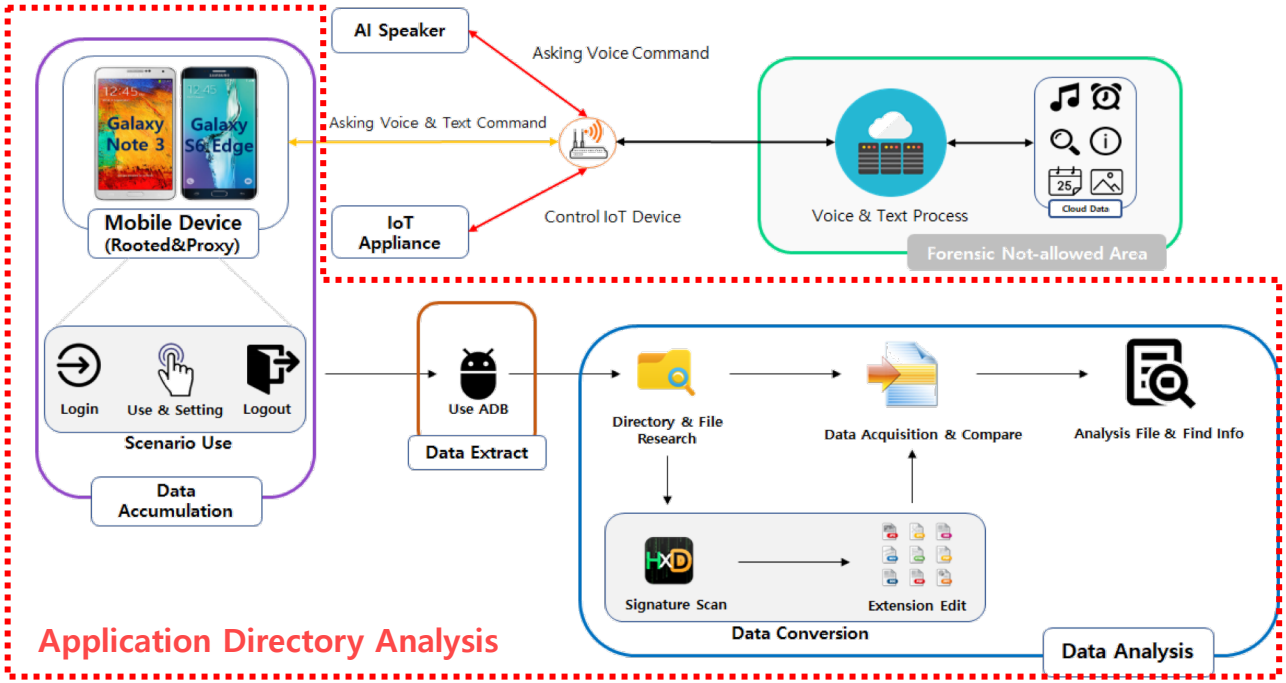


Proxy settings and certificate installation screen on smartphone



Fiddler View

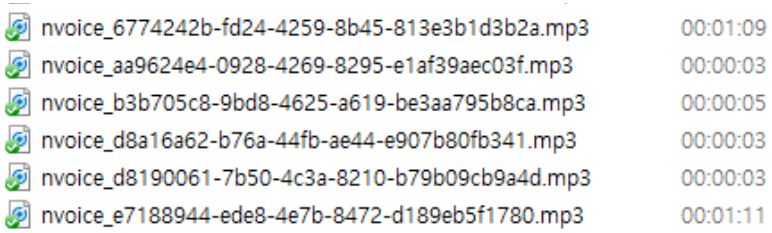
Methodologies
S03: Android Directory Analysis

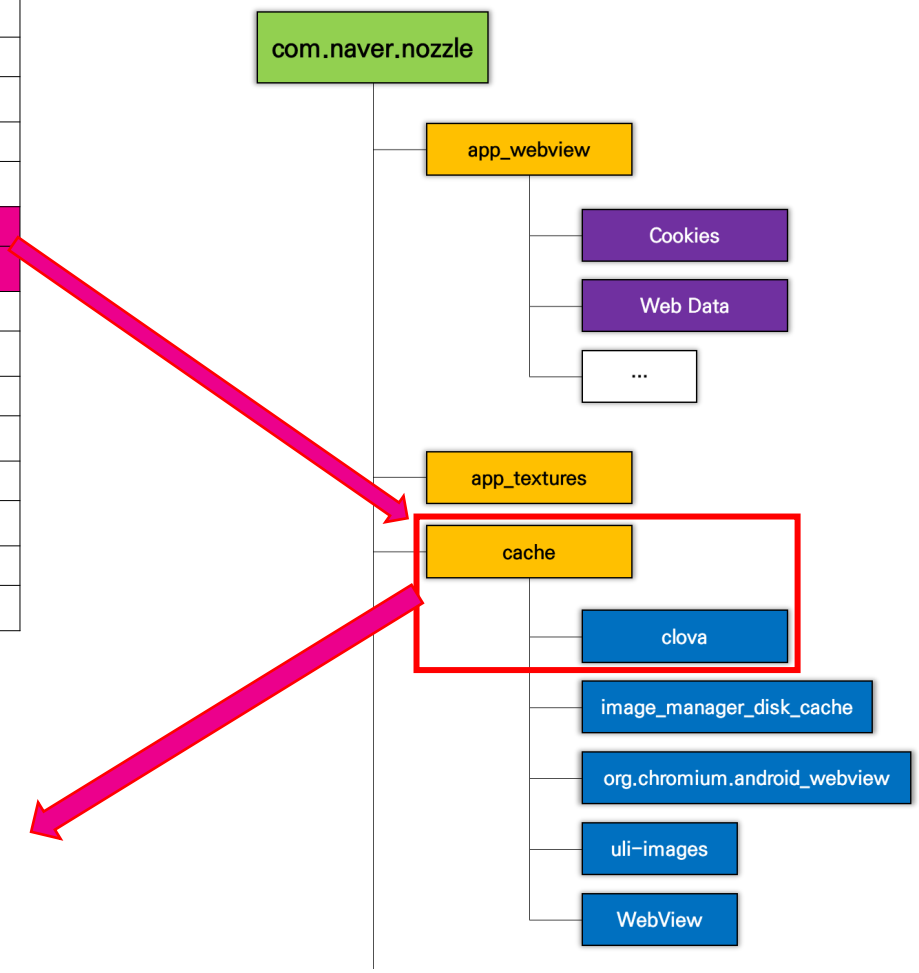


- **Scenario 3 analyzes the storage space of smartphone applications and extracts artifacts**
  - **AI application data accumulation**
    - It communicates with AI speakers, IoT devices, cloud servers, etc. and accumulates data in the internal directory
  - **Extract application data**
  - **Detailed analysis of collected data**

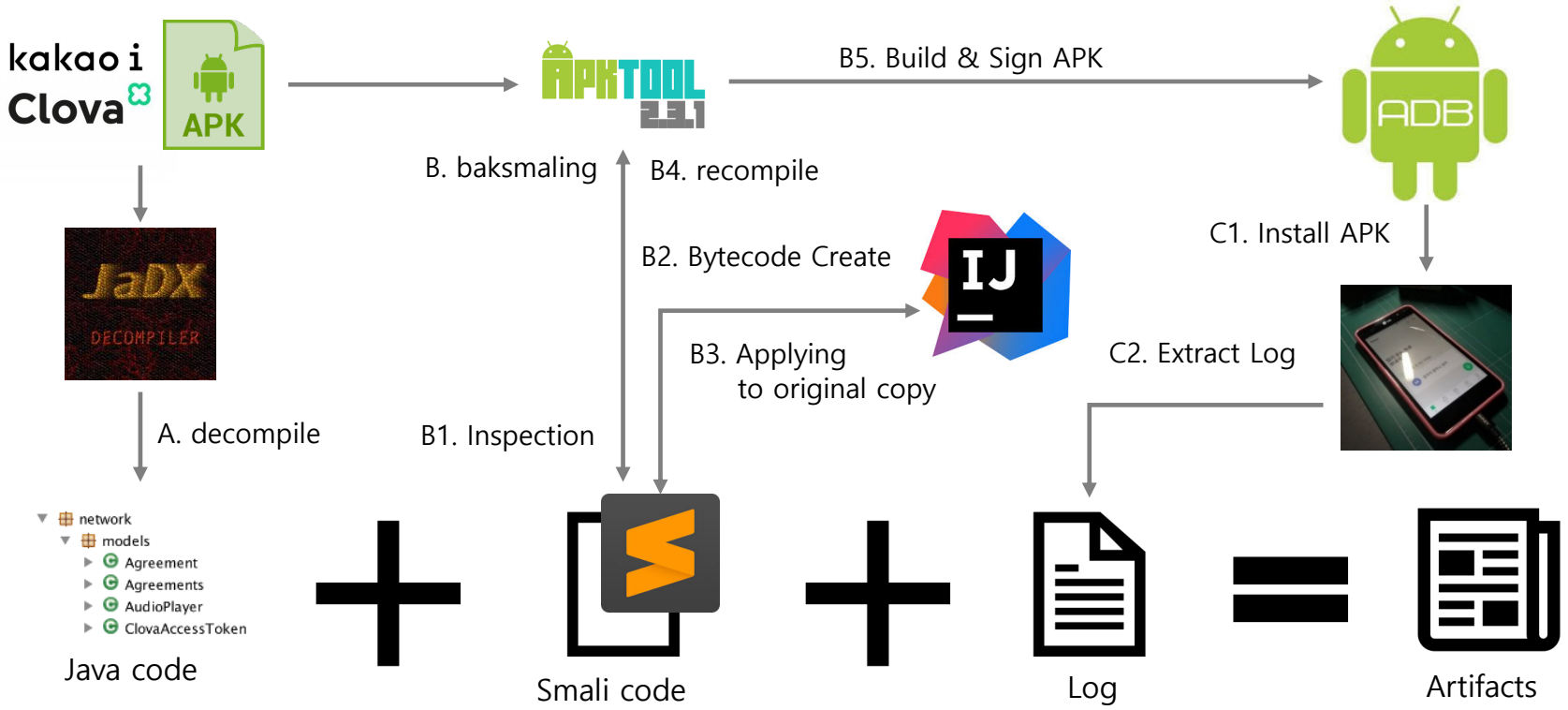
Methodologies
S03: Android Directory Analysis

Artifact Type	File Type	Path File Name
Cookie Data	SQLite DB	app_webview/ *
Webview Data	SQLite DB	app_webview/ *
Voice Response Cache Data	**MP3**	**cache/clova/** ***.mp3**
Cache Image Data	JPEG, PNG	cache/image_manager_disk_cache/ *.0
Cache Communication Data	GZIP	cache/org.chromium.android_webview/ *_0, *_1
User Setting Data	XML	shared_prefs/ clova.xml
Interlocking Account Data	XML	shared_prefs/ NaverOAuthLoginPreferenceData.xml





Methodologies
S04: APK Decompilation Analysis



Data Collection and Analysis Methods

- **A. Java code analysis after decompiling .apk file using JaDX**
- **B. Analyze Smali code after baksmaling .apk file using Apktool**
- **C. If Debug mode exists, modifies Flag value to True and re-installs output log analysis**
  - To avoid application tampering detection, only the apk where the Debug Flag exists (CLOVA case)

Methodologies
S04: APK Decompilation Analysis

Logcat to find artifacts

- **Step 1. Calling Clova speech recognizer (Trigger: saying wake-word or clicking voice button)**

```
08-09 01:39:51.351 23732 23732 D Clova.recognize.y: ClovaRequest=ai.clova.cic.clientlib.api.clovainterface.ClovaRequest@5d0339d
namespace=SpeechRecognizer name=Recognize dialogRequestId=3e983b9e-fa70-42d8-8fcf-050f8f738405 isDownchannel=false -called by a
08-09 01:39:51.352 23732 23732 D Clova.recognize.a: doOnSubscribe() dialogRequestId=3e983b9e-fa70-42d8-8fcf-050f8f738405 -calledby a
08-09 01:39:51.352 23732 23732 D Clova.recognize.g: doOnSubscribe dialogRequestId=3e983b9e-fa70-42d8-8fcf-050f8f738405 -called by a
08-09 01:39:51.353 23732 23910 D Clova.recognize.y:  -called by b
08-09 01:39:51.353 23732 23910 D Clova.DefaultSpeechRecognizerManager:  -called by b
08-09 01:39:51.361 23732 23732 D Clova.a :  -called by b
```

- **Step 2. Sending voice file to server via HTTP multipart body**

```
08-09 01:39:51.401 23732 23910 D r       : using resourceSupplier, cicRequest=Request{method=POST, url=https://prod-ni-cic.clova.ai/v1/events,
tags={}} clovaRequest=ai.clova.cic.clientlib.api.clovainterface.ClovaRequest@5d0339d namespace=SpeechRecognizer name=Recognize
dialogRequestId=3e983b9e-fa70-42d8-8fcf-050f8f738405 isDownchannel=false -called by a
08-09 01:39:51.401 23732 23910 D Clova.ClovaEventProtocolClient: doOnSubscribe dialogRequestId=3e983b9e-fa70-42d8-8fcf-050f8f738405 -called by a
08-09 01:39:51.403 23732 23814 D Clova.recognize.y:  -called by b
08-09 01:39:51.403 23732 23814 D CicRequestInterceptor:  -called by b
08-09 01:39:51.403 23732 23814 D CicRequestInterceptor:  -called by b
08-09 01:39:51.403 23732 23814 D CicRequestInterceptor:  -called by b
```

- **Step 3. Getting speech recognizer response from server via JSON**

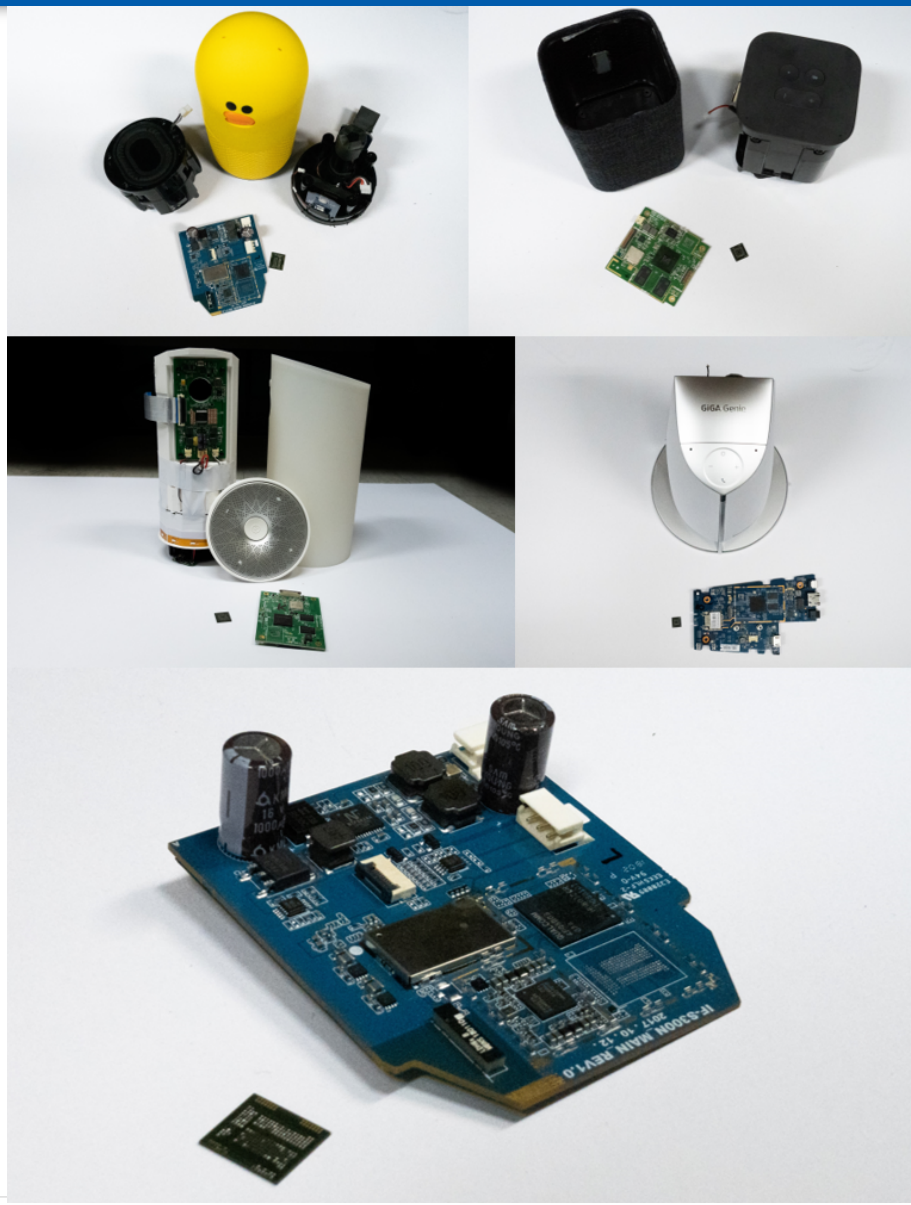
  (Repeat getting response from server until recognition procedure completes)

```
08-09 01:39:52.439 23732 23806 D Clova.data.ClovaServicePluginManager: responseBody={"directive":{"header":{"namespace":"SpeechRecognizer","name":"Show
RecognizedText","messageId":"c9216c84-ffa8-461c-8c01-4bfa4d59ae57","dialogRequestId":"3e983b9e-fa70-42d8-8fcf-050f8f738405"},"payload":{"text":"네"}}}
08-09 01:39:52.814 23732 23806 D Clova.data.ClovaServicePluginManager: responseBody={"directive":{"header":{"namespace":"SpeechRecognizer","name":"Show
RecognizedText","messageId":"67dd589e-028c-4f0f-9014-8fcfeb1839f6","dialogRequestId":"3e983b9e-fa70-42d8-8fcf-050f8f738405"},"payload":{"text":"내일"}}}
08-09 01:39:53.538 23732 23806 D Clova.data.ClovaServicePluginManager: responseBody={"directive":{"header":{"namespace":"SpeechRecognizer","name":"Show
RecognizedText","messageId":"1a7d2461-0199-4d80-bdbf-e9e0bfd20b2d","dialogRequestId":"3e983b9e-fa70-42d8-8fcf-050f8f738405"},"payload":{"text":"내일
날씨 어때"}}}
08-09 01:39:53.538 23732 23806 D Clova.data.ClovaServicePluginManager:  -called by e
08-09 01:39:53.540 23732 23806 D Clova.data.ClovaServicePluginManager: dialogRequestId=3e983b9e-fa70-42d8-8fcf-050f8f738405 Directive:
SpeechRecognizer.ShowRecognizedText -called by a
```

Methodologies
S05: Chip-off Image Analysis

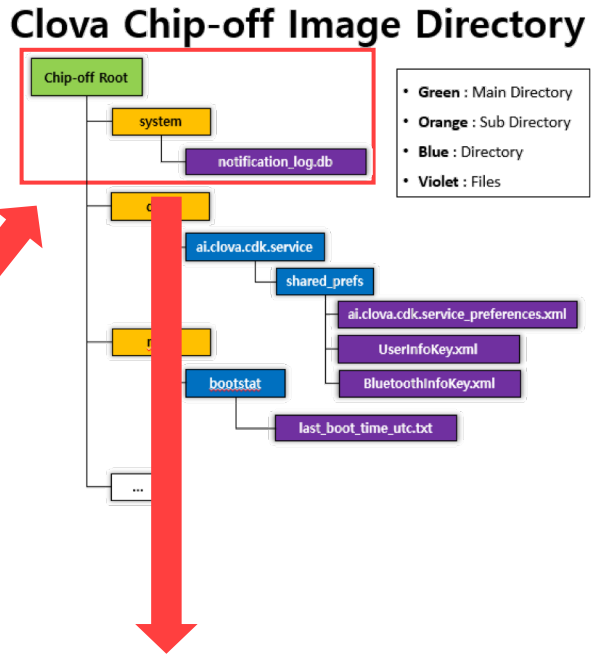
Data Collection and Analysis Methods

- **Filesystem identification**
  - Using signatures of the filesystems
- **Analyze operating system and directory structure**
  - Mount image and analyze as Scenario 3
- **Explore using file signatures and keywords**
  - Personal information or Key files(i.e. .mp3, .db)
- **Delete data recovery and comparison**
  - EXT4 recovery techniques using Journal area



Methodologies
S05: Chip-off Image Analysis

	Artifact Type	File Type	Path	File Name	Description
A	User Name	xml	root₩data₩ai.clova.cdk.service₩shared_prefs	BluetoothInfoKey.xml	
B	Personal Information	xml		UserInfoKey.xml	Address, Location (Latitude, Longitude)
C	Identification Information	xml		UserInfoKey.xml	User Key ID Wi-Fi mac address
D		xml		BluetoothInfoKey.xml	Connected Smartphone (mac, model name)
E	Time Information	**db**	**root₩system**	**notification_log.db**	**Event Log**
F		txt	root₩misc₩bootstat	last_boot_time_utc.txt	Last boot time
H	History	mp3	-	nvoice_<hash>.mp3	Deleted



테이블(T): log

새 레코드

	_id	event_user_id	event_type	event_time_ms	key	pkg	nid	tag	when_ms
	필터	필터	필터	필터	필터	필터	필터	필터	필터
1	231	0	1	1530749597926	0|ai.clova.ap…	ai.clova.app.friendsalert	1	NULL	1530749597926
2	232	0	1	1530749601511	0|ai.clova.ap…	ai.clova.app.friendsalert	1	NULL	1530749601511
3	233	0	1	1530761391146	0|ai.clova.ap…	ai.clova.app.friendssettings	1	NULL	1530761391146
4	234	0	1	1530761391159	0|ai.clova.ap…	ai.clova.app.friendsknocker	1	NULL	1530761391159
5	235	0	1	1530761391651	0|ai.clova.ap…	ai.clova.app.friendssound	10015	NULL	1530761391651

Test Environments

AI Speaker Android Application Installed Base

- SAMSUNG Galaxy Note 2, Note 3, S7

Chip-off Image Analysis Devices

Vendor	Naver	Kakao	SKT	KT
Model	Friends (NL-S1000KRL)	Kakao Mini (KM-1000)	NUGU (NU100)	GiGA Genie (CT1100)
AI	Clova	Kakao I	Aria	Giga genie

Results

Appendix A. Summary of Key Artifacts

Category	*Vendor*	*AI Cloud (Packet Analysis)*	*Android mobile (Android Chip-off Analysis)*	*AI speaker (AI Speaker Chip-off Analysis)*
User Information: Information that can be used or helpful in identifying a user (e.g. user's name, Interlocking Account Data, MAC, address, ID, email, Key value, Wifi MAC, etc.)	NAVER	auth.clova.ai(/user_profile/personal_info/*) prod-ni-cic.clova.ai(/result/{DEVICE_#}/*)	shared_prefs/ (NaverOAuthLoginPreferenceData.xml clova.xml)	root\data\ai.clova.cdk.service\shared_prefs (BluetoothInfoKey.xml, UserInfoKey.xml)
	KAKAO	auth.kakao.com(/account/profile/*) app.i.kakao.com(/contents/{DEVICE_#})	shared_prefs/(CrashReporter.Crashlytics.xml)	P6\misc\bluedroid\(bt_config.xml) P6\data\com.kakao.i.speaker\shared_prefs\(kakaoi.pref.xml)
	SKT	api.sktnugu.com (/*, /simpleSetting/*, accountSetting/*)	shared_prefs/(optiondata.xml)	userdata\data\com.skt.aicloud.speaker.service\shared_prefs\(AICloud.xml)
	KT	gbas.megatvdnp.co.kr (/user*, /devList/*) gsvr.ktipmedia.co.kr (/devUserList/{USER_#}/*)	shared_prefs/(*.xml)	data\com.kt.gigagenie.launcher\databases\(launcherCommon.db)
Time: Hard to deduce a specific command, but relevant information to build an event timeline. (e.g., use time, boot time, end time, package usage history, and alarm setting history)	NAVER	prod-ni-cic.clova.ai (/meta/*)	app_webview/(*)	root\system\notification_log.db root\misc\bootstat\last_boot_time_utc.txt
	KAKAO	app.i.kakao.com (/result/result/*) app.i.kakao.com /alarms/{alarm #}	databases/(com.kakao.kinsight.sdk.android.~.sqlite)	data\com.android.providers.media\databases\(external.db)
	SKT	pif.t-aicloud.com (/clientStatus/*)	databases/(aladdin.db)	system\usagestats\(usage-history)
	KT	gdialog.ktipmedia.com	files/(dxshield.sys)	data\com.kt.gigagenie.tts\shared_prefs\(com.kt.gigagenie.tts.xml) system\(appops.xml)
History: Information about the command history that can be used to infer the user's command (e.g., cookie data, webview data, cache image, event recording)	NAVER	prod-ni-cic.clova.ai (/result/historyQuery/*)	cache/clova/(*.mp3) cache/org.chromium.android_webview/(*_0, *_1) cache/image_manager_disk_cache/(*.0)	[deleted] nvoice_{hash}.mp3
	KAKAO	kinsight-event.kakao.com (/sessions/events/*, /sessions/headers/*)	-	**data\com.android.providers.media\databases\(external.db)** **media\0\KakaoICache\audio\(cached.{hash}.mp3)**
	SKT	-	databases/(aladdin.db) cache/image_manager_disk_cache/(*.0) app_webview/(*)	data\com.skt.aicloud.speaker.service\databases\ (AladdinGeneral.db) system\recent_tasks\(#_task.xml) system\recent_images(#_task_thumbnail.png)
	KT	gdialog.ktipmedia.com	**cache/picasso-cache/(*.0, *.1)**	

Naver Clova's History

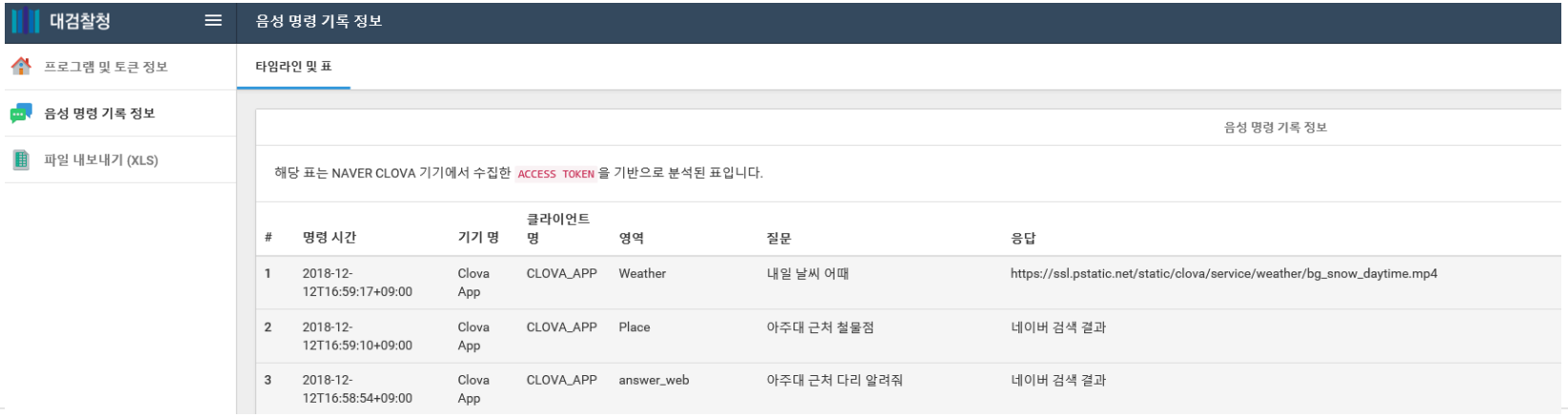
Differences from Clova application screen

- **Timestamp**
  - The application UI displays only the date, can not confirm the exact time.
- **Identification Information**
  - Identification information such as id, requestID, messageID, etc.,
- **Number of history (100 records at a time)**
  - The application UI displays only one or two records at a time, hard to see 100 records

Table 2. NAVER Clova's history artifact.

Field	Value
clientName	FRIENDS
deviceName	SALLY
dialogRequestId	09296c90-bd8e-4edf-af5a-3c35a40427c5
messageId	c2e8523c-b719-4f3e-ab5a-68736876ea9a
actionList::type	Action
actionList::value	clova://device-control?command=Increase&target=volume
paragraphText::type	String
paragraphText::value	Volume increased
domain	Control
query	Increase the volume three levels
id	586248fa-33d7-49f6-9203-c79935b7ea70
requestId	0c23cd9d-3368-48ee-bb63-5f4a91db343c
time	2018-06-21T13:58:59+09:00

meta : {'success': True, 'error': None, 'nextCursor': 1541075935000, 'current': 1542287739000}
result : {'id': 'f1476c8c-ec8d-4ca0-b867-c2b7b8d71d86', 'requestId': '792760f6-a640-4978-961b-d08a753d3120', 'time': '2018-11-05T16:57:11+09:00', 'type': 'Query', 'clientName': 'FRIENDS', 'deviceName': 'BROWN', 'historyQuery': {'query': '영어회화 틀어줘', 'domain': 'freetalking',
result : {'id': '6cea6d39-1405-4146-820c-72404e157d91', 'requestId': '1d25917e-17f5-435f-bda6-b54db7e1c376', 'time': '2018-11-05T16:56:49+09:00', 'type': 'Query', 'clientName': 'FRIENDS', 'deviceName': 'BROWN', 'historyQuery': {'query': '영어 듣기 틀어줘', 'domain': 'music', 'direct
result : {'id': '8dd9a80c-c61a-4850-becd-4cfd8a614459', 'requestId': '72f4d883-31a9-4a53-a085-26743615eed8', 'time': '2018-11-05T16:36:58+09:00', 'type': 'Query', 'clientName': 'FRIENDS', 'deviceName': 'BROWN', 'historyQuery': {'query': '아나두 영어', 'domain': 'answer_lang', 'dire
result : {'id': '216fb130-8b06-49c7-b91a-349cf14c841c', 'requestId': 'ff45abd0-2cc5-4f70-bc7a-4d59bea6bf99', 'time': '2018-11-05T16:36:48+09:00', 'type': 'Query', 'clientName': 'FRIENDS', 'deviceName': 'BROWN', 'historyQuery': {'query': '아나두 기초영어 회화', 'domain': 'none', 'di



Conclusion and Future Work

- **Personal information and ID artifacts**
  - **Law enforcement can request cooperation from service providers based on ID information**
  - **On most devices, the answers remain until reboot**
- **Classification of the server roles in the cloud**
  - **According to the type of information to be requested.**
  - **Confirmation of non-discrimination policy**
    - User's voice is not saved in device
- **Provide guidelines for the investigators when AI speakers are found in the field**
  - **The investigator can get personal information of user by chip-off image analysis**
  - **Compare Smartphone Mac address and Wi-Fi MAC address of user and suspect**
- **Present analysis directions for brand-new IoT devices through various approaches**
  - **Various approaches will be the base source to future works**
    - Rooting and Live Forensics on AI speaker / AI speaker application decompilation / AI speaker ROM to Raspberry Pi

Thank You

Contact Info.

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Wooyeon Jo