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# Mobile Forensic Tools Validation and Evaluation for Instant Messaging

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**Abstract**—Mobile technology is experiencing rapid development from year to year. Various types of models and operating systems are available on the market followed by the development of applications for mobile devices. Behind the development of mobile technology, mobile devices are often used for crime. To handle a case related to a mobile device, an investigator needs to use forensic methodologies and tools. The rapid development of mobile technology and the lack of understanding of forensic tools sometimes become an obstacle for an investigator in handling a case. This research conducted a forensic analysis of WhatsApp (WA) application on the Android 5.0 Lollipop and Android 6.0 Marshmallow operating systems. The parameters of the NIST forensic tool and additional parameters related to WA artifacts were used to evaluate forensic tools which will then be continued by calculating the index of acquisition capabilities of forensic tools. The capability index is expected to provide an overview and recommendations regarding forensic tools for conducting WA forensic analysis. Based on the acquisition capability index, Magnet AXIOM has advantages over Forensic Oxygen and WA Key/DB Extractor.

**Keywords**— mobile forensics; NIST; WhatsApp; validation; acquisition.

## I. INTRODUCTION

WhatsApp (WA) is one of smartphone applications that is quite popular. This can be seen from the increase in the number of WA users from year to year. WA globally has increased the number of active users per month as shown in Fig. 1. In April 2013 WA had a total of 200 million users per month and in December 2017 WA had 1.5 billion users per month [1]. WA had a total of 20.5 million users in 2017 in the United States and it is predicted that by 2021 there

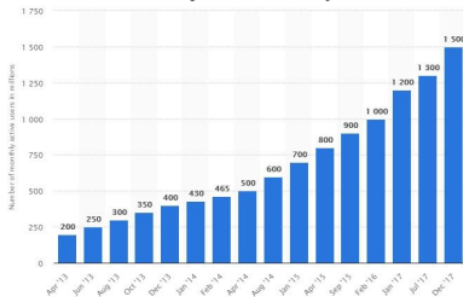


Fig. 1 Number of Monthly Active WA Users Globally

will be 25.6 million users as shown in Fig. 2 as in [2]. In Indonesia alone in March 2017 WA ranked first for the Instant Messaging application with 35.8 million users [3]. Reference [4] stated that WA is a popular Instant Messaging application on smartphones with a percentage value of 60%, followed by Viber and Telegram.

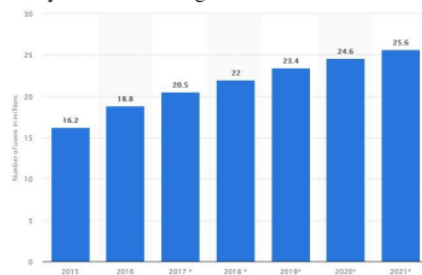


Fig. 2 Number of WA Users in United States of America

Behind the popularity of WA, there have been several cases of crimes involving WA such as media to spread hoaxes, sexual harassment, pornography, bullying, drug trafficking, human trafficking, and data theft [5], [6], [7],

[8]. WA also has been used as a tool to search for evidence in handling crime cases [9], [10].

To handle a case with evidence in the form of a mobile device a specific forensic methodology is needed. Reference [11] in their publication, explained a forensic methodology known as the National Institute of Standards and Technology forensic methodology (NIST). This publication explained the methodology for conducting forensic mobile analysis consisting of preservation, acquisition, examination & analysis, and reporting stages. This publication also discussed forensic tool validation technique, and explained artifacts from smartphone devices that can be used as an evidence such as: contact lists, text messages, instant messaging conversations, images, audio and video, document files, geolocation and so on.

There have been several studies related to the forensic mobile operating system of Android, WA, and other Instant Messaging applications. Reference [12] conducted a forensic analysis of WA applications on iPhone devices with the operating system of iOS 5.0.1 using Oxygen Forensic and UFED Cellebrite. From the experiment results, it can be seen that although Oxygen Forensic had access to limited devices compared to UFED Cellebrite in terms of Web History, Cookies, Passwords, User Accounts, and Web Bookmarks, Oxygen Forensic has the advantage of getting more information about the WA application.

Reference [13] conducted forensic analysis on Blackberry Messenger using NIST methodology and Andriller forensic tool. Researchers stated that NIST forensic methodology can be applied to digital evidence acquiring process from Blackberry Messenger on Android operating system..

Reference [14] conducted forensic analysis using Oxygen Forensic and MOBILedit tools. From the research it can be seen that MOBILedit has a faster performance than Oxygen Forensic. Researchers also argue that live analysis is not recommended in the process of investigating a case involving a smartphone device because it can damage the evidence. Each forensic tool has its own strengths and weaknesses. For this reason, it is necessary to use more than 1 forensic tool in handling a case.

Reference [15] conducted a comparison of the capabilities of forensic tools in data acquisition from smartphone devices. The parameters used in this test are runtime and the type of acquisition (live or static). From the testing, it can be seen that the Forensic Toolkit is superior in terms of runtime compared to Digital Detective Blade v1.13 and Kernel Database Recovery. The researcher also recommends using the Forensics Toolkit for static type data.

Reference [16] in their research, tested the validation of the forensic WA Key/DB Extractor 4.7 and Belkasoft Evidence resulting in a fact that forensic tool used successfully fulfilled the Samsung Galaxy S4 artifact validation test. Although they did not succeed in getting all the artifacts, the forensic tools were stated to fulfill repeatability and reproducibility tests as the similar artifacts and same number of artifacts were found.

Reference [17] stated that Android devices have dominating the smartphone market. For this reason, an understanding and solution is needed to investigate a case related to Android devices. Knowing the type of software and hardware from an Android device is crucial to determine

the type of forensic tool used to conduct an investigation. Hence, we need a standard to measure the performance of forensic tools. Reference [18] and [19] in their publication, discussed the standards of forensic tools and features that should be owned by a forensic tool. These features include the acquisition process and the ability of forensic tools to make acquisitions on a logical, physical, and UICC basis.

Mobile forensic has several challenges such as: the absence of a standard method for data acquisition processes, the large number and version of the operating system for smartphones which makes it necessary to update forensic tools and techniques for conducting mobile forensic [20], [21], [22]. Reference [23] added that the rapid development of mobile technology such as the emergence of new models and types of smartphones, operating system updates, hardware and software updates become a challenge for forensic analysts to be able to adjust to such changes.

From explanation above, researchers conducted forensic analysis of the WA application and tool evaluation. The forensic tools used in this research were Oxygen Forensic, Magnet AXIOM (trial ver), and WiKey/DB Extractor. Samsung Galaxy S4 and Samsung A3 devices with Android 5.0 Lollipop and Android 6.0 Marshmallow were used for experiment. Android Lollipop and Android Marshmallow are Android operating systems that are widely used by smartphone users [24]. The differences between this research and previous studies is that this research emphasizes on the validation aspects of forensic acquisition and evaluation of forensic tools using the parameters of forensic tools from NIST and additional parameters focused on WA artifacts on Samsung Galaxy S4 and Samsung A3 devices. This research was expected to provide recommendations for mobile forensic tools and help investigators to handle cases related to WA and Android devices.

## II. MATERIALS AND METHOD

### A. Materials

The materials used in this research were divided into 2 types, hardware and software. Table 1 shows the hardware used for the research. This research used 2 smartphone devices as research objects which were, Samsung Galaxy S4 with the Android version 5.0 Lollipop and Samsung A3 with the Android version 6.0 Marshmallow. Desktop computers used as workstations for analysis and USB connectors were used as a medium to connect smartphone devices to desktop workstations. Table 2 shows the software used in the research. The software used was divided into software test, operating systems, forensic tools, and analysis tools.

TABLE I  
HARDWARE MATERIALS

No	Hardware	Description
1	Samsung Galaxy S4 GT-I9500	Android Lollipop, Unrooted, Experiment Device
2	Samsung A3 SM-A310F	Android Marshmallow, Unrooted, Experiment Device
3	Desktop, Intel i5-4440, 8,00 GB RAM	Windows 7 64 Bit
4	USB Connector	Smartphone and workstation connecting device

TABLE II  
SOFTWARE MATERIALS

No	Software	Version	Description
1	WhatsApp	2.17.351	Testing Software
2	Windows 7		Workstation Operating System
3	WA DB/Key Extractor	4.7	Forensic Tool
4	Oxygen Forensic 4.7	6.4.0.67	Forensic Tool
5	Magnet AXIOM	2.7.1.12070	Forensic Tool
6	Igorware Hasher x64		Hashing Tool

### B. Method

This research focused on validation process and forensic tools evaluation. Therefore researchers used 2 approaches. Fig. 3 shows validation stages used in this research. In the Simulation stage, researchers simulated the use of the WA application on Samsung Galaxy S4, Samsung A3, and Samsung C9 Pro. The simulations resembled the daily use of WA applications such as sending and receiving messages, voice and video calls, and transferring files in the form of images, videos and documents.



Fig. 3 Validation Stages

In the Forensic Analysis stage, forensic analysis was carried out using the forensic methodology from NIST which has 4 stages, namely: Preservation, Acquisition, Examination & Analysis, and Reporting. After the Forensic Analysis stage, result analysis was conducted. In the Result Analysis stage, validation and analysis of results from Forensic Analysis stage were carried out. Validation was conducted to prove that the forensic process and forensic tools are suitable for use and the results can be accepted as evidences before law. There were 2 main validation stages: repeatability and reproducibility. Repeatability test is conducted by doing repeated testing 2 times or more of the same object using the same forensic tool within small time differences. At the reproducibility test a similar object will be tested using 2 or more different forensic tools within small time differences [11]. Hashing will be used as an additional validation tool. Reference [25] explained that hashing can be used to identify evidence, verify data, authenticate data, and view data integrity. The hashing value calculation is needed to find out the hashing value of a file.

The hashing value provides unique values regarding data as well as DNA testing. If the evidence is modified, the hashing value will be different [26]. Igorware Hasher x64 was used as a hashing tool to find and compare the hashing values of 2 or more artifacts from the acquisition of forensic tools. After validation stage, it was continued by analyzing the results using measurement parameters.

Forensic tools evaluation conducted by analyzing forensic process and forensic results as shown in Fig. 4. Mobile forensic tools parameters used in this research. NIST in the publication entitled "Mobile Device Specification Tool Version 2.0" and "Mobile Device Test Tool Assertions and Test Plan Version 2.0" provided parameters regarding forensic tools [18], [19]. Table 3 shows the parameters of the NIST forensic tool used in this research to analyze and measure the results of the forensic process. This research was limited to logical acquisitions by adjusting to the conditions of the smartphone devices used in the experiment. Physical acquisition was not used because the smartphone devices used in the research were unrooted and the UICC was not used because WA artifacts are not at the UICC.



Fig. 4 Tools Evaluation Stages

TABLE III  
NIST FORENSIC TOOLS PARAMETERS

Core Assertions	Core Assertions
MDT-CA-01	MDT-CR-01 A
MDT-CA-02	MDT-CR-02 A
MDT-CA-03	MDT-CR-03 A
MDT-CA-04	
MDT-CA-05	
MDT-CA-06	
MDT-CA-07	
MDT-CA-08	
MDT-CA-09	

TABLE IV  
WA ARTIFACTS PARAMETERS

Artifact
WA Contact List
WA Logs
Text
Image
Video
Document

This research applied additional parameters in the form of WA artifacts as in Table 4 to strengthen the analysis of the abilities of forensic tools in conducting WA forensic analysis [27]. The analysis results were then calculated using an unweighted index number and ended with the conclusion stage where the researcher drew conclusions from the research. Index numbers provide a comparison of values that are easy to understand and can be used for various types of data [28]. In this research index numbers were used to

determine the acquisition capabilities of forensic tools based on parameters from NIST with the calculation equation of:

$$P_{an} = \frac{P_n}{P_o} \times 100 \quad (1)$$

### III. RESULTS AND DISCUSSION

Validation aims to test that the forensic process and the evidence do not change and the integrity is maintained so that it can be recognized before the law. There are 3 types of validation tests used, namely: repeatability, reproducibility, and hashing. Repeatability and reproducibility were main validation tests. Hashing test were used as an additional validation test.

#### A. Repeatability

Table 5, Table 6, and Table 7 shows the results of repeatability test performed on Samsung Galaxy S4 devices. The forensic tools used successfully made acquisition on Samsung Galaxy S4 device artifacts. From the repeatability test, it can be seen that the number of artifacts obtained from 2 different acquisition processes have the same number of artifacts.

TABLE V  
REPEATABILITY TEST ON SAMSUNG GALAXY S4 USING OXYGEN FORENSIC

No	Artifact Type	Acquisition 1	Acquisition 2
1	Text	17	17
2	Image	629	629
3	Video	18	18
4	Document	11	11
5	Contact List	910	910
6	WA Log	5	5

TABLE VI  
REPEATABILITY TEST ON SAMSUNG GALAXY S4 USING MAGNET AXIOM

No	Artifact Type	Acquisition 1	Acquisition 2
1	Text	-	-
2	Image	640	640
3	Video	1	1
4	Document	4	4
5	Contact List	333	333
6	WA Log	-	-

TABLE VII  
REPEATABILITY TEST ON SAMSUNG GALAXY S4 USING WA KEY/DB EXTRACTOR

No	Artifact Type	Acquisition 1	Acquisition 2
1	Text	44	44
2	Image	3	3
3	Video	-	-
4	Document	-	-
5	Contact List	1173	1173
6	WA Log	2	2

Oxygen Forensic successfully made acquisition on Samsung A3 device but did not get any WA artifacts as shown in Table 8. Table 9 shows the number of artifacts from acquisition using Magnet AXIOM. Magnet AXIOM did not able to retrieved Text artifact and WA Log artifact. WA Key/DB Extractor did not successfully carry out the acquisition process so it did not get artifacts from Samsung A3 device as shown in Table 10.

TABLE VIII  
REPEATABILITY TEST ON SAMSUNG A3 USING OXYGEN FORENSIC

No	Artifact Type	Acquisition 1	Acquisition 2
1	Text	-	-
2	Image	-	-
3	Video	-	-
4	Document	-	-
5	Contact List	-	-
6	WA Log	-	-

TABLE IX  
REPEATABILITY TEST ON SAMSUNG A3 USING MAGNET AXIOM

No	Artifact Type	Acquisition 1	Acquisition 2
1	Text	-	-
2	Image	12448	12448
3	Video	116	116
4	Document	49	49
5	Contact List	350	350
6	WA Log	-	-

TABLE X  
REPEATABILITY TEST ON SAMSUNG A3 USING WHATSAPP KEY/DB EXTRACTOR

No	Artifact Type	Acquisition 1	Acquisition 2
1	Text	n/a	n/a
2	Image	n/a	n/a
3	Video	n/a	n/a
4	Document	n/a	n/a
5	Contact List	n/a	n/a
6	WA Log	n/a	n/a

Table 11 shows the repeatability test results of the forensic tools used in the research. All forensic tools used successfully fulfill repeatability tests for logical acquisition on Samsung Galaxy S4 device. For repeatability tests on Samsung A3 device, only WA Key/DB Extractor did not meet the test because WA Key/DB Extractor could not make an acquisition. Oxygen Forensic did not retrieved any WA artifacts on Samsung A3. Even so, Oxygen Forensic was stated to fulfill repeatability test because of same number of artifacts other than WA artifacts were found from 2 successful acquisition processes.

TABLE XI  
REPEATABILITY TEST RESULTS

No	Smartphone Device	Oxygen Forensic	Magnet AXIOM	WA Key/DB Extractor
1	Samsung Galaxy S4	√	√	√
2	Samsung A3	√	√	-

#### B. Reproducibility

Table 12 shows the results of the reproducibility test for forensic tools used. All forensic tools used fulfilled the logical reproducibility acquisition tests on Samsung Galaxy S4 device. Although the number of artifacts from acquisition result using Oxygen Forensic and Magnet AXIOM were different, Oxygen Forensic and Magnet AXIOM met the Reproducibility test due to the similarity of the artifacts from WA acquisition result. WA Key/DB Extractor did not meet the reproducibility test for Samsung A3 device as it could not make an acquisition so no artifacts were obtained.

TABLE XII  
REPRODUCIBILITY TEST ON SAMSUNG GALAXY S4

No	Artifact Type	Oxygen Forensic	Magnet AXIOM	WA Key/DB Extractor
1	Text	17	-	44
2	Image	629	640	3
3	Video	18	1	-
4	Document	11	4	-
5	Contact List	910	333	1173
6	WA Log	5	-	2

Oxygen Forensic successfully made acquisition on Samsung A3 device but did not succeed in finding any WA artifacts as shown in Table 13. Even though Oxygen Forensic failed to get WA artifacts, artifacts other than WA were successfully obtained so that they could be used as comparative artifacts to test the reproducibility test. Magnet AXIOM managed to get images, videos, documents, and contact list artifacts. WA Key/DB Extractor had no results because it did not successfully make acquisition on Samsung A3 device. Seeing the explanation above, Oxygen Forensic and Magnet AXIOM successfully met the reproducibility test. WA Key/DB Extractor failed to make an acquisition.

TABLE XIII  
REPRODUCIBILITY TEST ON SAMSUNG A3

No	Artifact Type	Oxygen Forensic	Magnet AXIOM	WA Key/DB Extractor
1	Text	-	-	n/a
2	Image	-	12448	n/a
3	Video	-	116	n/a
4	Document	-	49	n/a
5	Contact List	-	350	n/a
6	WA Log	-	-	n/a

Table 14 shows the results of the reproducibility test of forensic tools on Samsung Galaxy S4 and Samsung A3 device. From the table it can be seen that Oxygen Forensic and Magnet AXIOM fulfilled the reproducibility tests on Samsung Galaxy S4 and Samsung A3 device. WA Key/DB Extractor only managed to meet the reproducibility test on

TABLE XVI  
SAMSUNG GALAXY S4 ARTIFACTS HASH VALUE COMPARISON

No	Forensic Tools	Artifact	Acquisition Date & Time	File Size	SHA-1 HashValue
1	Oxygen Forensic	1	26 December 2017/11:59	94.752 KB	78282a2517f63ca5e461120745b482f9fa5c77a1
2		2	26 December 2017/17:49	94.752 KB	06d6bb69930b1e40e1274bd154cc86cb28516ce95
3	Magnet AXIOM	1	23 December 2017/19:01	15.388.672 KB	0b82b1e5526aec5486a951325304ac2310a227fc
4		2	23 December 2017/22:07	15.388.672 KB	6762c552366b126ebae268f960ecab8a1b168806
5	WA Key/DB Extractor	1	21 December 2017/18:07	296 KB	073bf62a45c1f4c94f98b616948ac8ad1ad835c4
6		2	21 December 2017/18:09	296 KB	073bf62a45c1f4c94f98b616948ac8ad1ad835c4

TABLE XVII  
SAMSUNG A3 ARTIFACTS HASH VALUE COMPARISON

No	Forensic Tools	Artifact	Acquisition Date & Time	File Size	SHA-1 Hash Value
1	Oxygen Forensic	1	2 March 2018/15:39	5.600 KB	a88f21327f8eae7606480908b9af26a57895e018
2		2	2 March 2018/15:41	5.600 KB	5be0f96057f05dd650299c9af82155ed84b33130
3	Magnet AXIOM	1	21 December 2017/10:50	1.863.266 KB	90ca69d68aa2fa4ea98741de21e75fd8f0a58c3c
4		2	21 Decemb 7 2017/11:24	1.864.437 KB	ef8d468e61b6e43741807517540c659d1414bdc2
5	WA Key/DB Extractor	1	n/a	n/a	n/a
6		2	n/a	n/a	n/a

Samsung Galaxy S4 devices. WA Key/DB Extractor did not met reproducibility test on Samsung A3 because failed to make an acquisition so it did not have artifacts that could be used for comparison.

TABLE XIV  
REPRODUCIBILITY TEST RESULTS

No	Smartphone Device	Oxygen Forensic	Magnet AXIOM	WA Key/DB Extractor
1	Samsung Galaxy S4	√	√	√
2	Samsung A3	√	√	-

### C. Hashing

Table 15 and Table 16 show a comparison of the hashing values of Samsung Galaxy S4 and Samsung A3 artifacts as a result of acquisition of Forensic Oxygen. From the table we can see that the hashing values of Artifacts 1 and Artifacts 2 for both devices are different. Hash value testing shows that almost all forensic tools do not meet the hashing values tests as shown in Table 17. This is understandable because the object of testing in the form of a smartphone device has a dynamic and ever-changing environment [11]. Of the 3 forensic tools used, only the WA Key/DB Extractor had successfully fulfilled the hashing test for Samsung Galaxy S4 device artifacts. WA Key/DB Extractor's artifacts had the same hashing values because WA Key/DB Extractor only made acquisition on databases from WA. The artifacts of other forensic tools had different hashing values because they conducted full acquisition of smartphone devices used for testing. With full acquisitions, slight changes in mobile devices such as changes in date and time could affect the value of hashing.

TABLE XV  
HASH VALUE TEST RESULTS

No	Smartphone Device	Oxygen Forensic	Magnet AXIOM	WA Key/DB Extractor
1	Samsung Galaxy S4	-	-	√
2	Samsung A3	-	-	-

#### D. Analysis of Acquisition Capabilities Index of Forensic Tools

The index shows the performance of forensic tools based on the parameters used. The parameters used in this research were forensic tool parameters from NIST and additional parameters focused on WA artifacts [18], [19], [27]. Table 18 shows the results of evaluating forensic tools for logical acquisition on Samsung Galaxy S4 using the Android 5.0 Lollipop operating system. Oxygen Forensic did not successfully meet MDT-CA-02, MDT-CA-03, MDT-CA-04, and MDT-CR-02A parameters. Oxygen Forensic successfully met all WA artifact parameters. The Magnet AXIOM just did not meet MDT-CA-04 and MDT-CR-02A parameters. The Magnet AXIOM failed to fulfill the WA log artifact parameters and text message artifact parameters. WA Key/DB Extractor only managed to get 4 parameters from NIST, which were MDT-CA-07, MDT-CA-08, MDT-CR-01A, and MDT-CR-03A. However, WA Key/DB Extractor successfully met the artifact parameters of the WA contact list, WA log artifacts, text message artifacts, and image file artifacts.

TABLE XVIII  
SAMSUNG GALAXY S4 LOGICAL ACQUISITION EVALUATION RESULTS

Parameters		Forensic Tools		
		Oxygen Forensic	Magnet AXIOM (Trial ver)	WA Key/DB Extractor
Core Assertions	MDT-CA-01	√	√	√
	MDT-CA-02	-	√	√
	MDT-CA-03	-	√	-
	MDT-CA-04	-	-	-
	MDT-CA-05	√	√	-
	MDT-CA-06	√	√	√
	MDT-CA-07	√	√	√
	MDT-CA-08	√	√	√
	MDT-CA-09	√	√	-
Core Features Requirements	MDT-CR-01 A	√	√	√
	MDT-CR-02 A	-	-	-
	MDT-CR-03 A	√	√	√
Logical Acquisition Artifact	WA Contact List	√	√	√
	WA Log	√	-	√
	Text	√	-	√
	Image	√	√	√
	Video	√	√	-
	Document	√	√	-

Equation (1) was used to calculate the ability index of a forensic tool to make logical acquisitions. From Table 14 it can be seen that the ability index of Oxygen Forensic to make logical acquisitions on the Samsung Galaxy S4 is  $(14/18) \times 100 = 77.77\%$ . Magnet AXIOM had an acquisition capability index of  $(14/18) \times 100 = 77.77\%$ . WA Key/DB Extractor had an acquisition ability index of  $(8/18) \times 100 = 44.44\%$ .

Table 19 shows the results of evaluating forensic tools for logical acquisition on Samsung A3 device using the Android

6.0 Marshmallow operating system. From the table it can be seen that Oxygen Forensic did not succeed in fulfilling NIST MDT-CA-02, MDT-CA-03, MDT-CA-04, and MDT-CR-02A parameters, nor did Oxygen Forensic succeed in fulfilling additional parameters regarding the WA artifacts provided. The Magnet AXIOM failed to meet NIST MDT-CA-04 and MDT-CR-02A parameters. Magnet AXIOM successfully fulfilled the parameters of contact list artifact, image file artifacts, video file artifacts, and document file artifacts. WA Key/DB Extractor did not succeed in fulfilling all parameters used because it could not perform logical acquisition processes on Samsung A3 device.

TABLE XIX  
SAMSUNG A3 LOGICAL ACQUISITION EVALUATION RESULTS

Parameters		Forensic Tools		
		Oxygen Forensic	Magnet AXIOM (Trial ver)	WA Key/DB Extractor
Core Assertions	MDT-CA-01	√	√	√
	MDT-CA-02	-	√	√
	MDT-CA-03	-	√	-
	MDT-CA-04	-	-	-
	MDT-CA-05	√	√	-
	MDT-CA-06	√	√	√
	MDT-CA-07	√	√	√
	MDT-CA-08	√	√	√
	MDT-CA-09	√	√	-
Core Features Requirements	MDT-CR-01 A	√	√	-
	MDT-CR-02 A	-	-	-
	MDT-CR-03 A	√	√	-
Logical Acquisition Artifact	WA Contact List	-	√	-
	WA Log	-	-	-
	Text	-	-	-
	Image	-	√	-
	Video	-	√	-
	Document	-	√	-

From Table 19 the ability index of logical acquisition of forensic tools can be calculated using Equation (1). Oxygen Forensic had an ability index of  $(8/18) \times 100 = 44.44\%$ . The Magnet AXIOM had an ability index of  $(14/18) \times 100 = 77.77\%$ . WA Key/DB Extractor did not succeed in making logical acquisitions on Samsung A3.

#### IV. CONCLUSIONS

From the results can be seen that forensic tools used met validation tests for logical acquisition on Samsung Galaxy S4. WA Key/DB Extractor failed to fulfill validation tests for logical acquisition on Samsung A3 therefore WA Key/DB Extractor not recommended to conduct forensic analysis on Samsung A3.

Oxygen Forensic and Magnet AXIOM have the ability index to make logical acquisitions on Samsung Galaxy S4 devices which are equal to 77.77%. Magnet AXIOM had the advantage of acquiring WA artifacts that could not be done by Forensic Oxygen such as WA log artifacts and text messages. Even though WA Key/DB Extractor had the

smallest ability index, WA Key/DB Extractor successfully met contact list artifact parameters, WA log artifacts, text message artifacts, and image file artifacts. The highest ability index for logical acquisitions on Samsung A3 was obtained by Magnet AXIOM with a value of 77.77% and followed by Oxygen Forensic with a value of 44.44%. WA Key/DB Extractor did not succeed in making logical acquisitions on Samsung A3. Magnet AXIOM and Oxygen Forensic managed to meet most of the NIST parameters used. However, the Magnet AXIOM outperformed Oxygen Forensic in fulfill the additional parameters of the WA artifact provided by the researcher.

From the research it can be concluded that the acquisition ability index can be used to assist investigators in determining the type of forensic tool that should be used to handle a case related to WA on a device with the Android operating system. From the results obtained, the researcher argued that the acquisition ability with unweighted value index was deemed not to reflect the ability of forensic tools accurately due to several parameters that had a greater role than other parameters in helping to find evidence on a mobile device. For that in the future it is necessary to do analysis with different calculations to get more accurate results. Mobile forensic analysis related to Instant Messaging applications other than WA on the latest Android operating system or other operating systems also need to be done given the diversification that exists in mobile technology.

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