



**UNIVERSITÄT PADERBORN**  
*Die Universität der Informationsgesellschaft*



**Android App Analysis**

University of Paderborn  
Warburger Str. 100  
33102 Paderborn

**PAndA<sup>2</sup>**  
**User Manual**

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**Authors:**

Abhinav Solanki	Anand Devarajan
Arjya Shankar Mishra	Fabian Witter
Felix Pauck	Monika Wedel
Pham Thuy Sy Nguyen	Ram Kumar Karuppusamy
Sriram Parthasarathi	

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# 1 Glossary

In this section, a brief explanation of specific subject, text, dialect or term specifically related to tool is explained.

## 1.1 Analysis

- **Permission Usage (Intra App- Level 1)**  
This analysis uses the capabilities of our tool in order to check if an application is or might be using any permissions.
- **Information Flow (Intra App- Level 2a)**  
This analysis analyses an application to detect whether there is critical information flow inside that application.
- **Permission Usage (Inter App- Level 2b)**  
This type of analysis is an extension to the previously described Permission Usage (Intra App- Level 1). In addition to the Permission Usage (Intra App- Level 1), this analysis will identify cooperations between different applications instead of only detecting the possibility of such a cooperation.

## 1.2 Permission Group

A permission is a restriction limiting access to a part of the code or to data on the device. The limitation is imposed to protect critical data and code that could be misused to distort or damage the user experience [2]. We have divided permissions into five groups, which are as follows-

- **MISSING** This contains set of permissions which are used in the application source code, but are not defined in the Manifest file.
- **REQUIRED** This contains set of permissions which are used in the application source code and are defined in the Manifest file.
- **MAYBE\_REQUIRED** This contains set of permissions which may have been indirectly used in the application source code and are defined in the Manifest file.
- **UNUSED** This contains set of permissions which are not used in the application source code and are defined in the Manifest file.
- **MAYBE\_MISSING** This contains set of permissions which may have been indirectly used in the application source code and are not defined in the Manifest file.

# 2 Requirements

Some of the basic requirements of the tool are listed out in this section.

## 2.1 System requirements

### 2.1.1 Software requirements

**JAVA** Java Runtime Environment (JRE) is required to run PAndA<sup>2</sup>. For that purpose, JDK8 is needed to be installed on the system. The installation procedure is described in the next section (refer section 3.1). Java Runtime Environment (JRE) will get installed when we install Java Development Kit (JDK). The standard JDK directory structure also comes with JavaFX integrated into it.

**Graphviz** To display graphical results in Information Flow (Intra App- Level 2a) analysis, Graphviz is required. Graphviz is open source graph visualization software. Graph visualization is a way of representing structural information as diagrams of abstract graphs and networks [1]. Installation procedure and requirements of Graphviz are described in next section (refer section 3.2).

**PDF Reader** Portable Document Format (PDF) reader is required to be installed on the system to view documents.

### 2.1.2 Hardware requirements

PAndA<sup>2</sup> does not have any specific hardware requirements but software requirements. Given below are some basic hardware requirements-

- CPU Architecture - x86(32-bit) for Windows, Linux
- JavaFX Graphics Support - Desktop GPUs (GMA 4500, GMA HD), Quadro FX 300 series or higher, Radeon HD 2400 series or higher

## 2.2 Resource requirements

**.apk file** Android application package (APK) is the package file format used by the Android operating system for distribution and installation of mobile apps and middleware [3].

**.pa2 file** This is a binary file which is structured to store graphical and textual result.

## 2.3 User requirements (Knowledge)

Basic user's *knowledge in head* requirements are as follows-

- Sound knowledge of using Java in command line prompt (CMD)
- Aware of setting path variables required to install Graphviz

## 3 Installation

### 3.1 Java

Java Runtime Environment (JRE) comes along with JDK8, the installation details can be found under JRE Installation.

- Procedure for installing it on Microsoft Windows is given under Windows Installation.
- Procedure for installing it on Linux is given under Linux Installation.

### 3.2 Graphviz

Steps to install *Graphviz* are as follows.

- Download *graphviz* – 2.38 from here [Graphviz Downloader](#).
- Install *Graphviz* and copy the location of the bin folder in *PATH* variable

## 4 About - Quick Start Guide

User Manual PAndA<sup>2</sup> will provide the information needed for a better Human Computer Interaction. After reading the manual, user will be able to perform the desired operations on the tool. The user will be in a condition to navigate through the tool with knowledge of possible outcomes of his actions. In the former sections, technical details have been shared with the user regarding system requirements and installation procedure. Upcoming sections will cover the Broadway of the tool.

In the subsequent section, certain basic functionalities of the tool are covered on an abstract level, at which the categorization of actions or events while the demonstration is done. As we have stated that the tool will provide two interfaces to the user to interact with. Both the interfaces are presented in the later section which makes the user familiar with the tool. The basic goal kept in mind during the designing of GUI (Graphical User Interface) was to keep the things simple, accessible, universal, use of standard notations.

A basic demo case is also depicted to the user to give a walk-through of a user story. It will cover the basic functionalities mentioned with both the interfaces in order to make sure that user will have a complete idea of the processes involved while executing the tool. It will cover a short example to make to enhance usability, user experience and accessibility.

In the end, when all the details, functionalities, walk through are covered, a section for Frequently Asked Questions is added aiming to cover up the questions that might emerge in the user's mind about the tool while working over it. In case, the user is getting confused at certain points, a reference to this section would probably help and it could also prove to be a good idea to have a look at the common expected questions before moving on further.

## 5 Functionalities

This tutorial will focus on five categorized functionalities of the tool covering both the interfaces, the brief description of them are given hereunder-

### 5.1 Start Analysis

This document will help the user to start an analysis, i.e. how to create the new analysis, how to initiate the analysis procedure in Command Line Interface. For every goal, there is always the first step, here it is initiated or start analysis. For both the interfaces, the method to start the analysis is explained in the later section (refer section 6).

### 5.2 Parameters Initialization

To set up an analysis, certain parameters are needed to be passed. Some of them are compulsory, others are optional based on the requirements of the analysis. This document will enable the user to get familiar with the input parameters in both the graphical and command line interface with special focus to command line interface.

During GUI interaction, the user will be able to choose the desired option with mouse click while during command line interaction, the user is expected to remember or keep in hand predefined parameters for specific functions to be operated, structure of command to follow. A short detail about them is included in this tutorial while covering the topic.

### 5.3 Result Representation

Result representation is by far the most important section, it deals with the convey of fruitful information to the user. The result is represented in user in two forms i.e. *Textual* and *Graphical*, both are shown during the illustration of the Graphical User interface. *Metadata* (data about data) has also been induced to the result section for the better understanding of the user like *Statistics* and *Legend*.

Every possible measure is considered to keep the information as simple as possible and self-explaining. During analysis phase, users will be timely notified about the status of the tool via status section at the bottom of the graphical user interface. It will display messages, if it encounters any during processing.

## 5.4 Result Filter

Result field can be huge at times, therefore filter functionality is provided with the tool to filter the result. The result can be filtered on specific predefined sections like *DetailLevel* and *PermissionGroups*. The user will be able to select associated filters with different type of analyses, e.g. *PermissionUsage(IntraApp – Level1)* and *PermissionUsage(InterApp – Level2b)*. User is supposed to get minor change in filters. User can make his selection from the list. A brief explanation of the filters is provided in the later section (refer section 6.1.4).

## 5.5 Saving and Comparing Result

After the user is finished with the analysis, he will see either the analysis result of current application or its comparison with previously saved result file providing that a previous saved result was provided to the tool while setting input parameters of analysis. User can also opt for saving the current comparison result.

## 5.6 Open Previous Result

Apart from starting a fresh analysis, user can also opt to open a previously saved result .pa2 file present in the system. The saved result will contain both the textual and graphical representations in SUMMARY as well as COMPARISON mode.

# 6 Interface

In this section, description of all the functionalities covered in previous section (refer section 5) with respect to both the type of interfaces is covered in detailed.

## 6.1 GUI

This section will provide instructions on how to carry out the functionalities of the tool in Graphical User Interface. The functionalities described above are chain activities performed one after another. This section will describe user all the functionalities in the same order as they are described in the former section and as they are practically carried out in the tool.

### 6.1.1 Start Analysis

When the tool is triggered in Graphical mode, home screen will look like as shown in fig 1. User can see in the image, the standard icons which clearly explain their functionality like *Zoom Buttons*. Here at this stage user can either choose to *Open previous result* by clicking on *File* menu or *New Analysis* by clicking on *New* icon on the toolbar. If the user is willing to get further information about PAndA<sup>2</sup>, user can click on *Help* and refer the documentation of tool. Now we assume the case that the user had chosen to start new analysis, further sections are illustrated accordingly.

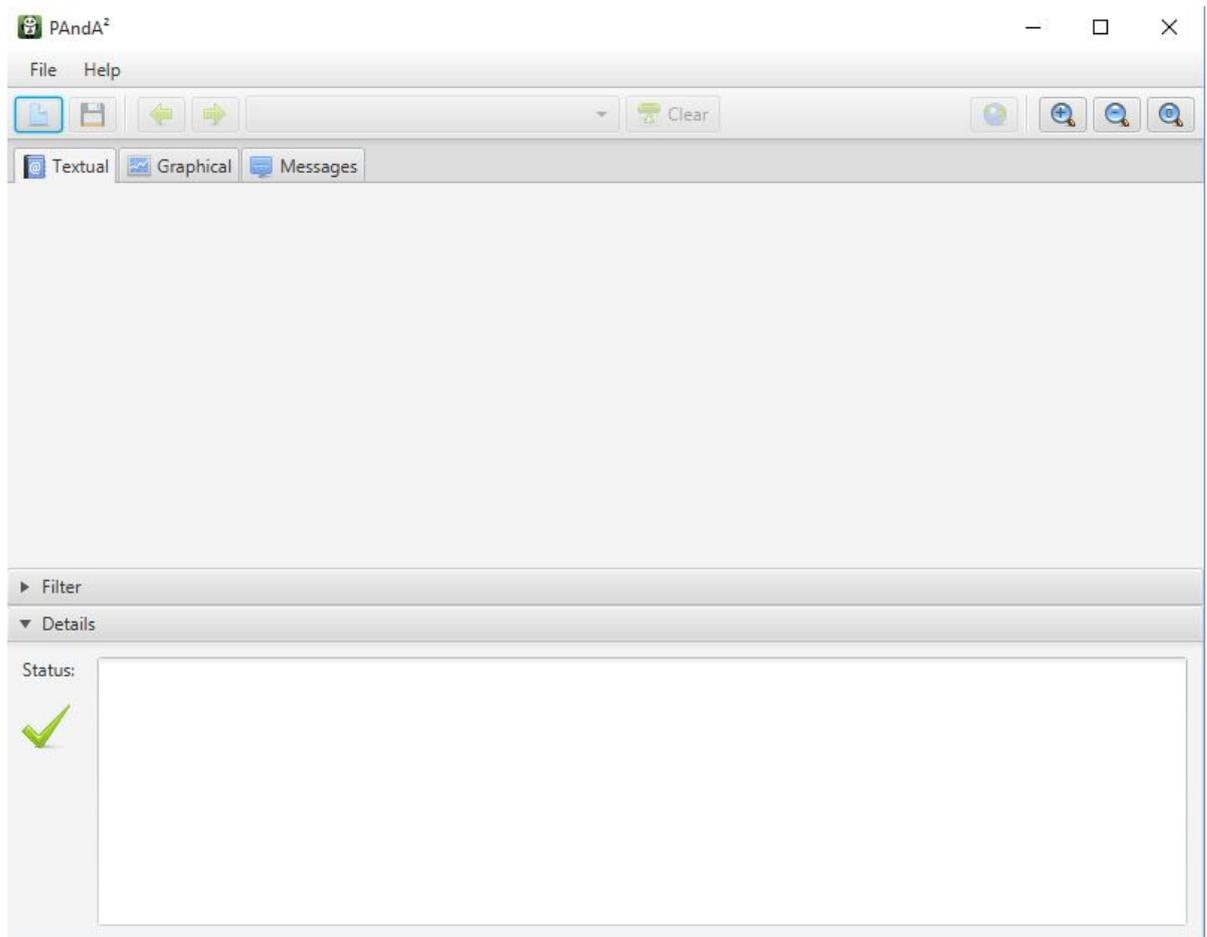


Figure 1: Home

### 6.1.2 Parameters Initialization

Now the next step is to set the parameters of the analysis. This process is carried out in two parts first part is shown in fig 2. The inputs for the first are as-



Figure 2: Input1

**Analysis** Here, user has to select analysis level out of three levels at which the tool performs the analysis. They are as follows-

- Permission Usage (Intra App- Level 1)
- Information Flow (Intra App- Level 2a)
- Permission Usage (Inter App- Level 2b)

**Mode (Optional)** This input depends on the input given in the first part i.e Analysis. In case, the user had selected *PermissionUsage(InterApp – Level2b)* in previous section Analysis, then only this will be available for selection. It provides user two options for mode selection, the user can choose any one of the two available. They are as listed-

- APP
- ALL

Now, after setting these input parameters, user needs to click on *Next* and move to next screen showing second part of setting parameters, as shown in fig 3. Now the user has three options in front, they are as follows-

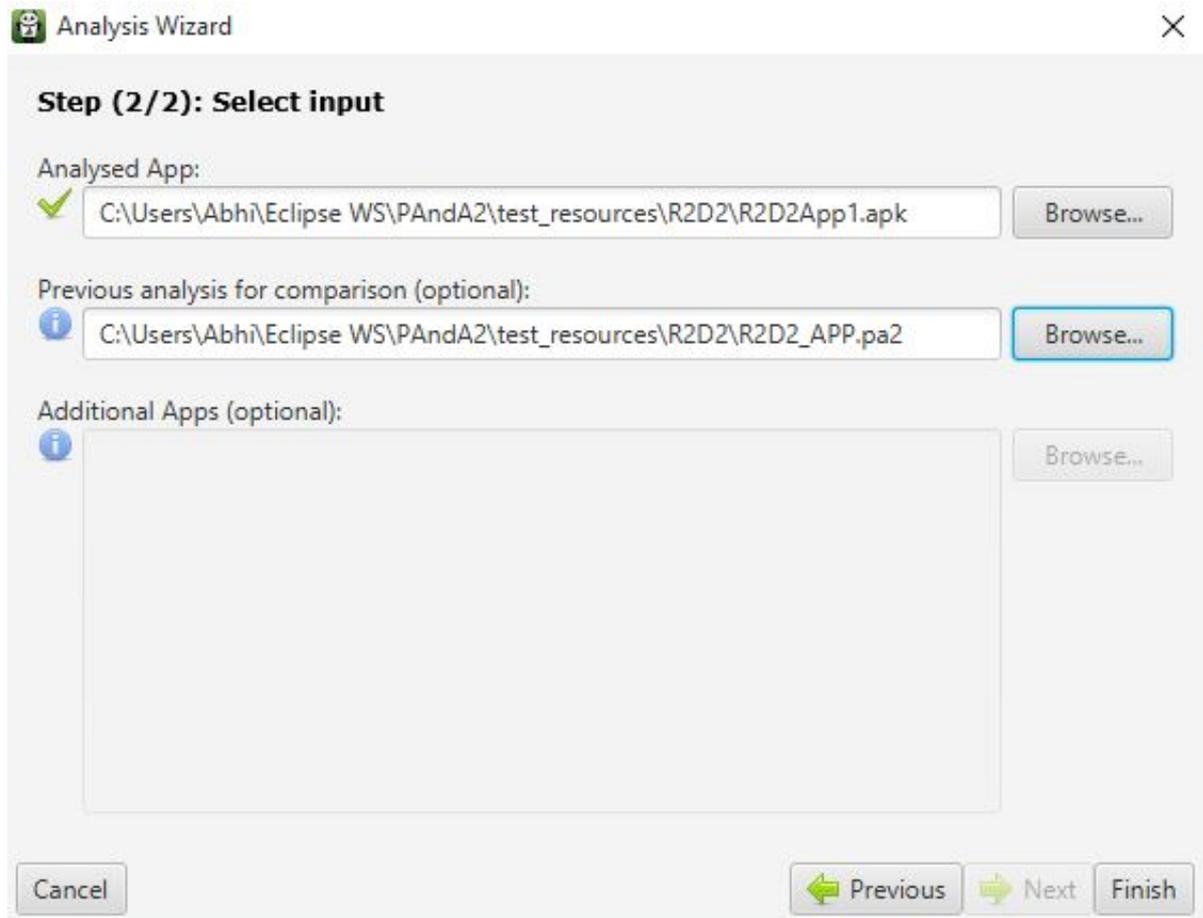


Figure 3: Input2

**Analysed App** The user has to provide the tool, the path of the application to analyze. When user click on *Browse* button on the right, file selection window will be pop up, then user can select the application path by traversing through directories. This input is mandatory.

**Previous analysis for comparison (Optional)** As the name suggests optional, this is not a mandatory field but if the user wants to compare the analysis result with some previous saved result, then it is needed here to provide the `.pa2` file (previous saved analysis result) or `.apk` file.

**Additional Apps (Optional)** This depends on the input given in the first part when setting these parameters i.e *Analysis* and *Mode*. If the user had selected *PermissionUsage(InterApp – Level2b)* as the first option, then the user will have the option to provide other multiple .apk files to the tool even it is not mandatory in specific selection. *Browse* button will trigger file selection window in which user can select multiple .apk files stored in the same repository. For other selections in *Analysis*, tool will neglect this field.

After going through all the input parameters, if the user is satisfied with inputs, then he can proceed to the analysis by clicking on *Finish* button or *Previous* button to make changes with the inputs provided.

Clicking on *Cancel* button at input window anytime will close the current window and the user will be returned to home screen as it was before the start of the analysis.

### 6.1.3 Result Representation

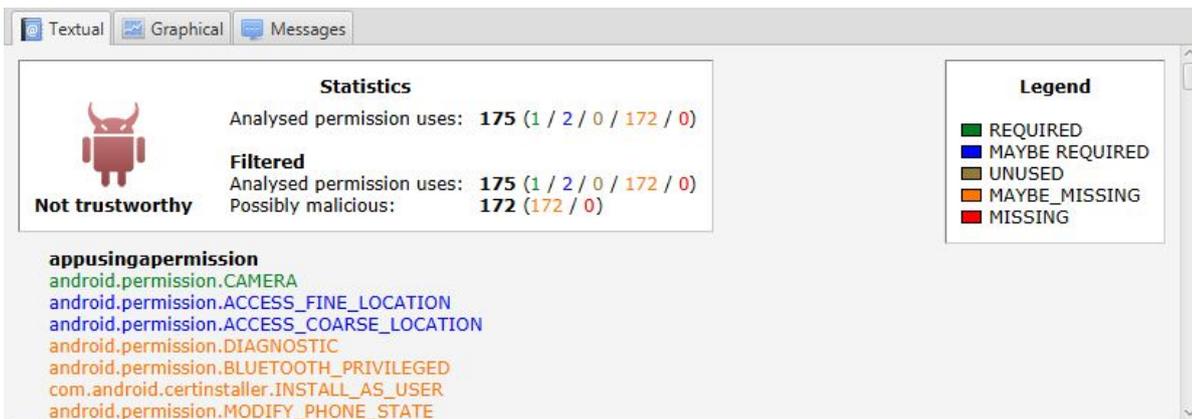


Figure 4: Textual Result

In the previous section, the user has gone through initialization of the parameters and then started the analysis. The tool will take its time to analyze the application and then will show the result to the user in two forms i.e Textual representation as shown in fig 4. and Graphical representation as shown in fig 5. User can switch between them through *TabPane*. There is also a third selection available i.e *Messages*. It will show messages generated when the tool was processing the analysis. There will be a third option on Tab pane i.e. *MessagesTab*, which will contain suggestions, errors and warnings with respect to the analysis as shown in fig 6. User can also view textual and graphical result in Web browser by clicking on *Browser* button on the toolbar.

**Statistics** The statistics as shown in the fig 7 for *PermissionUsage(IntraApp – Level1)*, *PermissionUsage(InterApp – Level2b)*, will give stats of the permissions in the analyzed

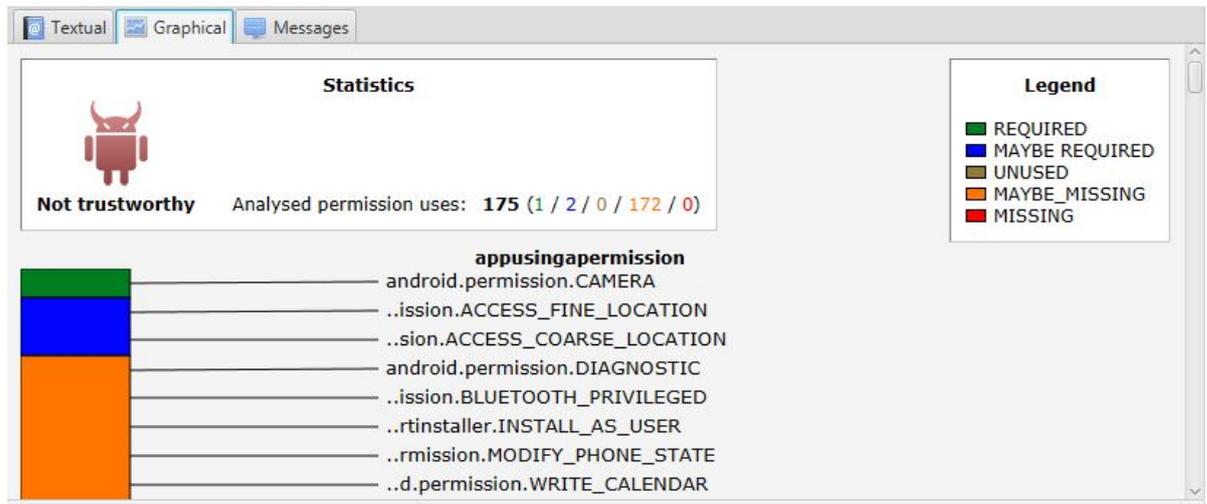


Figure 5: Graphical Result



Figure 6: Messages Tab

application like Analyzed permission uses and along with it shows the number of permissions in different categories explained by *Legend* and in fig 8 for *InformationFlow(IntraApp – Level2a)* it will tell number of source and sink permissions and the path between them. It will give the user brief idea about the application size and result size, it will help the user to opt for specific filters, which are described in later sections. On the top, it will also tell the user, whether the application is trustworthy or not.

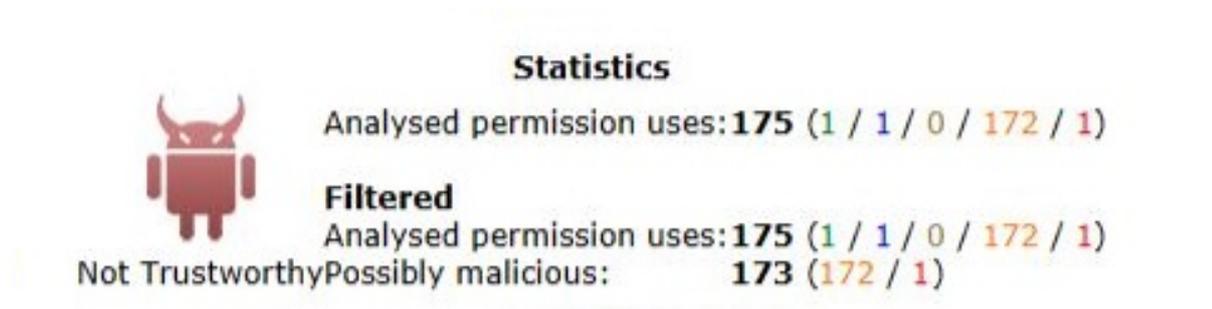


Figure 7: Statistics Permission Usage (Intra App- Level 1), Permission Usage (Inter App- Level 2b)

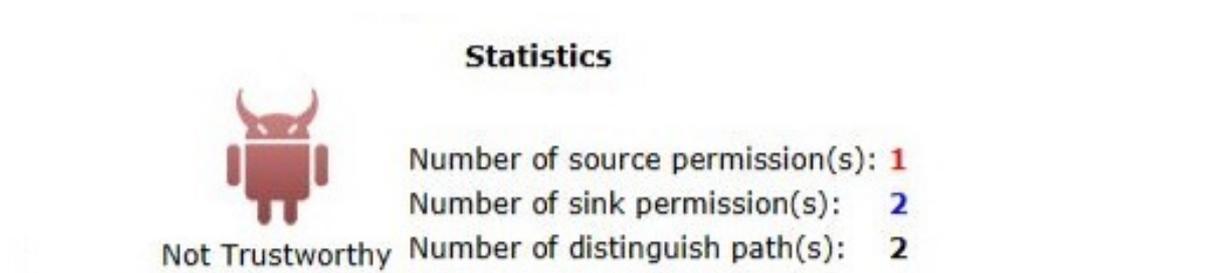


Figure 8: Statistics Information Flow (Intra App- Level 2a)

**Legend** This shows predefined categorized set of permissions common for all the applications and analysis assigned specific colors along with any rule defined to display the result. It shows different sectors in which permission can lie depending on the analysis and type of result, every category will have its own different color which makes clear visual understanding when looking at the permissions result set. For specific level, there can be addition parameters, for example in case of *LegendsPermissionUsage(IntraApp – Level1)* legends would look like as shown in fig 9, for *InformationFlow(IntraApp – Level2a)* legends would look like as shown in fig 10, for *PermissionUsage(InterApp – Level2b)* legends would look like as shown in fig 11.

**Permissions (appusingapermission)** This section will provide us with a list of all the permissions in the analyzed application in specific colors as categorized and shown in *Legend* in the above section and is the core result section. This list can be huge at times, so the whole representation is put on a scrollable object, we can scroll using the scroll bar to iterate through



Figure 9: Legends Permission Usage (Intra App- Level 1)



Figure 10: Legends Information Flow (Intra App- Level 2a)

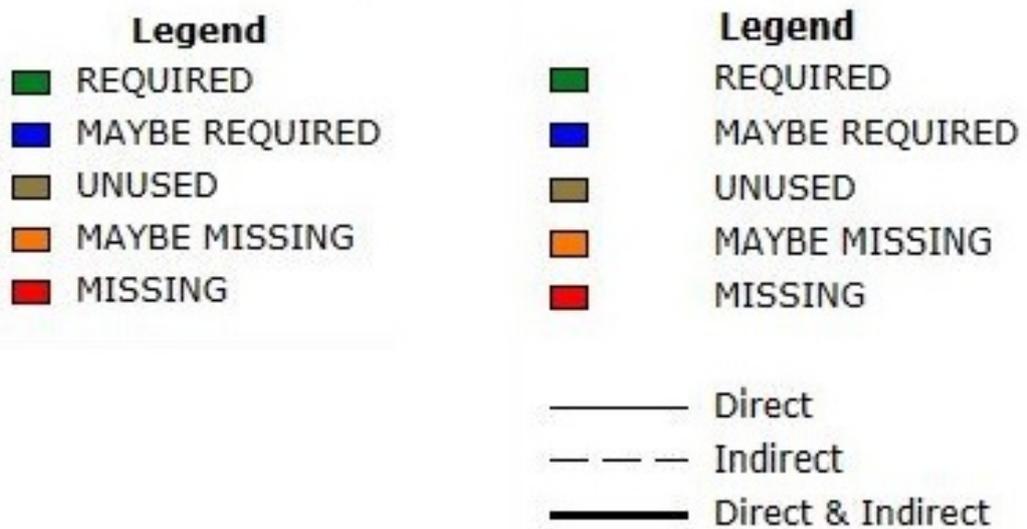


Figure 11: Legends Permission Usage (Inter App- Level 2b)

all the permissions in the section.

#### 6.1.4 Result Filter

As discussed in the above section that the result section can be huge at times, so the tool come along with the feature to filter the result, User can filter the result in certain categories depending on the type of analysis chosen while setting up the parameters. There are three types of filters depending on the *Analysis* selected by the user. Here is brief explanation of the selections.

If the user had chosen *PermissionUsage(IntraApp – Level1)* while setting the parameters, filters will be same for textual and graphical result, and will be available as shown in fig 12 in two categories, which are as flows-

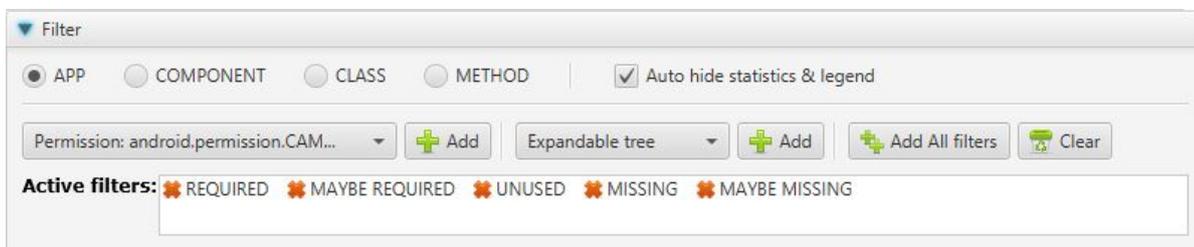


Figure 12: Filter-Permission Usage (Intra App- Level 1)

**Detail Level** Here, users can choose out of the four options available for selection, they are as follows-

- **APP**  
If user wants to view the permissions at the Application level, then user should select this option. This is the default selection and will show the result at this level by default until and unless the user choose some other filter in the same set.
- **COMPONENT**  
The user selects this option to list the permissions into components of the application. This is usually preferred if there is more than one component in the application and user wants to see the permissions component wise.
- **CLASS**  
This filter categorizes the permissions in classes where they are used. Selecting this option will list all the permissions under the classes linked to them.
- **METHOD**  
This filter will go a step further and will list all the permissions method wise i.e. it will list all the methods and under them the permissions linked to them. This filter option is suggested to opt in case user wants to go in depth or figure out specific activity.

Detail Level filters can be combined with the next filter section in any combination. The constraint on first filter section is that users can opt only one filter while in the second filter section user can have multiple choices. The second filter section is described here under-

**Permissions Group** In this section, users can filter the permissions on the basis of their usage, as described by the *Legend* in the section above. User can make multiple selections at this filter as well. The filters available in this section are as follows-

- **REQUIRED**
- **MAYBE REQUIRED**
- **UNUSED**
- **MAYBE MISSING**
- **MISSING**

Multiple selection here means that users can opt more than one filter from the above at the same time and user can also combine them with the filters available in previous section *DetailLevel filters* e.g *CLASS*, *COMPONENT* etc. This section will have all the options selected in default mode and will remain in that until the user makes its choice.

In case, the user had chosen *InformationFlow(IntraApp – Level2a)* while setting the parameters, filters will be available as shown in fig 13 in two categories, which are as flows-

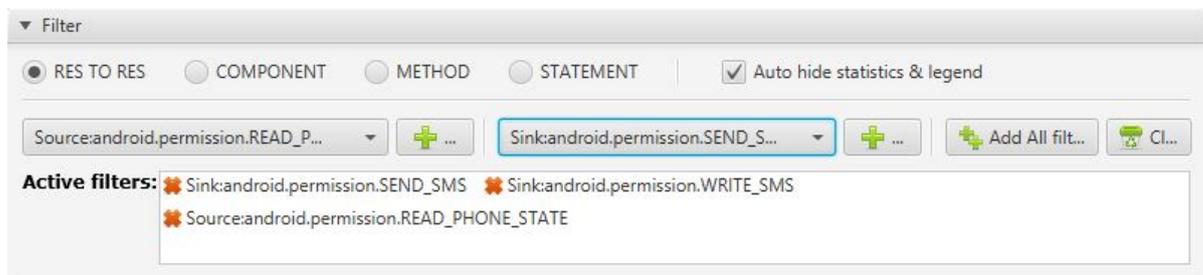


Figure 13: Filter-Information Flow (Intra App- Level 2a)

**Detail Level** Detail level filters at this analysis selection will consist of following three filters.

- **RES TO RES**  
This will present the user the flow from resources to resources, if exists any.
- **COMPONENT**  
This will present the user the flow from one component to another component.
- **STATEMENT**  
This presents the user the flow from statements to statements.

**Source/Sink filter** This filter can let user filter sources and sinks in the result. User can make a set of sources or single source to filter out the sink permissions.

A third case, if the user opted for *PermissionUsage(InterApp – Level2b)* while setting the parameters, filters will be available as shown in fig 14 in two categories, which are as flows-

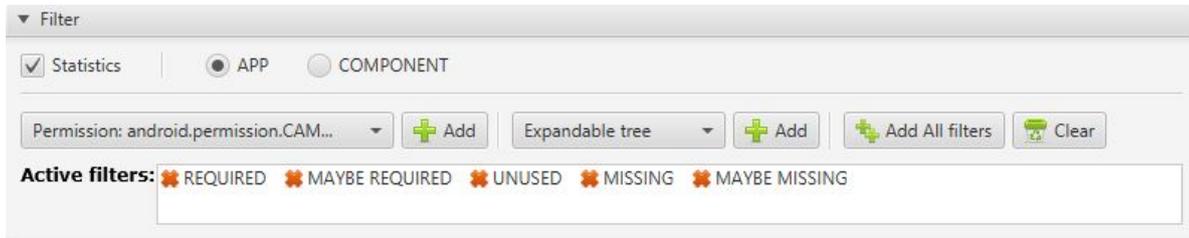


Figure 14: Filter-Permission Usage (Inter App- Level 2b)

**Detail Level** The functioning of this filter is similar to *PermissionUsage(IntraApp – Level1)* but Detail level filters at this analysis selection will consist of following two filters.

- **APP**

If user wants to view the permissions at the Application level, then user should select this option. This is the default selection and will show the result at this level by default until and unless the user choose some other filter in the same set.

- **COMPONENT**

The user selects this option to list the permissions into components of the application. This is usually preferred if there is more than one component in the application and user wants to see the permissions component wise.

**Permissions Group** This filter is exactly similar to the filter in *PermissionUsage(IntraApp – Level1)* and contains following filters.

- **MISSING**
- **REQUIRED**
- **MAYBE\_REQUIRED**
- **UNUSED**
- **MAYBE\_MISSING**

### 6.1.5 Saving and Comparing Result

As soon as the analyses are finished, we can see the result on the screen, then we can filter and view it or can directly go *Saving* or *Comparison*. The options for the following functions can be seen in fig. 15 and fig. 16.

**Saving** When we have result in front of us on the screen, we can click on the *Save* button to save the result. Clicking on *Save* button will trigger a dialog box in which we have to input the name of the result file. We can choose the location or can use the predefined location, the result file will be having default extension `.pa2`, we cannot change the extension of result file here.

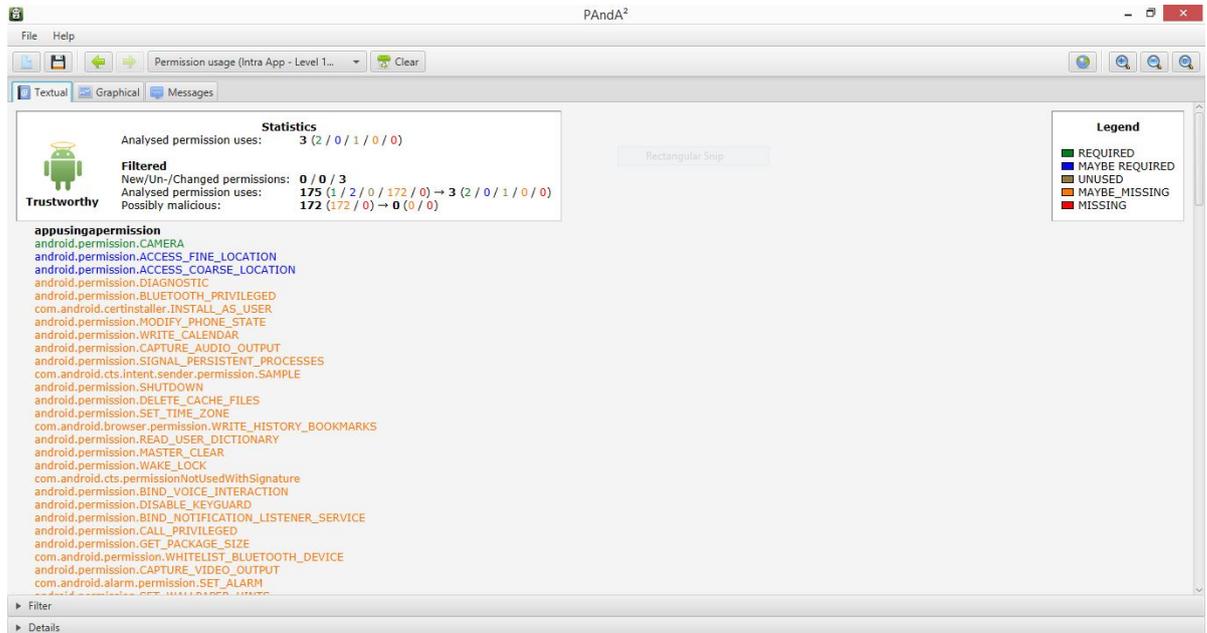


Figure 15: Comparison-Textual

**Comparison** The other option we have when analysis is finished and we have the result on our screen, is *Comparison*, provided we have given the file for comparison while setting the parameters of analyses. The comparison file is the previous saved result from another analysis. Comparison result will also have textual and graphical representations as shown in fig. 15 and fig. 16 respectively. The graphical comparison result and statistics part in textual result will give better understanding to the user. User can switch between them from Tab pane.

### 6.1.6 Open Previous Result

Instead of going through the complete process described in (refer section 6.1), user can open a previously saved SUMMARY or COMPARISON result file, which is a `.pa2` file. This can be done either by clicking on the *Open* button from *File* menu or by clicking on the *Next* icon on the toolbar.

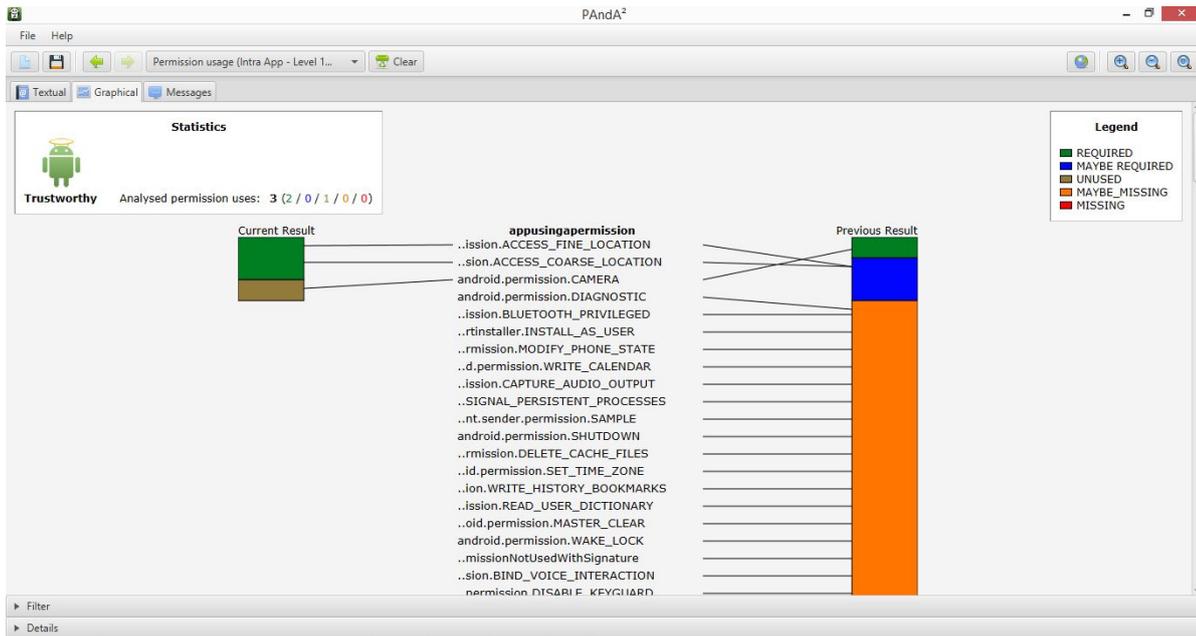


Figure 16: Comparison-Graphical

## 6.2 CLI

### 6.2.1 Starting application through CLI

Application can be started through runnable jar file using the command prompt. This can be done by giving the following command under the absolute path where our tool was available in your system:

- `Java -jar PandaA2.jar <command line parameters>`

### 6.2.2 CLI Parameters and its Description

With respect to using the CLI parameters for starting the application as well as for performing the functionalities similar to the GUI, please refer the following table contents.

- Tool Option CLI parameters (Please refer table 1).
- CLI Parameter Table : When Analysis Option was selected (Please refer table 2).
- Parameter Table : When Analysis (or) Load Option was selected (Please refer table 3).
- Sample CLI Arguments/Parameters Usage (Please refer table 4).

Parameters (Use any one of the parameter for using respective functionality)	Description	Default Selection	Other Valid Selections
-toolopt -opt -option	Parameters provides options for users in the tool so that they can use any one of the following functionality: Analysis (or) Load (or) Help	Analysis ("analyze", "ana", "analysis", "a"). No Need to give this parameter if you are going to analyse the app.	Load ("load", "l"). Help ("help", "h", "-help", "-h", "-man", "man"). <b>-opt help.</b> -opt load <other parameters>

Table 1: Tool Option CLI Parameters

Parameters	Description	Other Valid Selections	Compulsory field/ Usage example
-l -level	Analysis Level	LEVEL1: ("level 1", "l1", "1", "level1", "INTRA-APP-PERMISSION", "INTRA-PERM", "INTRA-APP-PERM")  LEVEL2A: ("level 2a", "l2a", "2a", "level2a", "INTRA-APP-INFO-FLOW", "INTRA-INFO-FLOW", "INTRA-IF")  LEVEL2B: ("LEVEL 2b", "l2b", "2b", "LEVEL2b", "INTER-APP-PERMISSION", "INTER-APP-PERM", "INTER-PERM")	YES (Compulsory)  -l 1 -level 1  -l 2a -level 2a  -l 2b -level 2b

-i -input	Initial APK File Input(s)	-	YES (Compul- sory)  <b>-i apkpath1 apkpath2</b>
-lm -levelmode	Analysis Level Specific Mode	<b>APP</b> <b>ALL</b> values are not case sensitive	YES (Com- pulsory for LEVEL2B)  <b>-lm app</b> <b>-lm all</b>
-nn -nonnative	Non native APK Files inputs	-	YES (Compul- sory for Level2B)  <b>-n apkpath1 apkpath2</b>
-ci -compareinput	Previous Analysis Input File for Com- parison Mode	-	YES (Com- pulsory for Comparison Mode)  <b>-i previous- ResultPath</b>

Table 2: CLI Parameter Table : (When Analysis Option was selected)

Parameters	Description	Default Se- lection	Other Valid Se- lections	Compulsory field/ Usage example
-r -result	Result Rep- resentation option which is used for Saving or Viewing the analysis result.	<b>View</b> (Value is not case sensitive)	<b>Save</b> (Value is not case sensitive)	NO <b>-r view</b> <b>-r save</b>

-v -view	Result View option which provides the user to view the result in different ways.	Textual ("T", "TEXT", "TEXTUAL")	Graphical ("G", "GRAPH", "GRAPHICAL")  Message ("M", "MSG", "MESSAGE")	NO (Compulsory) <b>-v t</b> <b>-v text</b> <b>-v graph</b> <b>-v g</b> <b>-v m</b> <b>-v msg</b>
-fp -filepath	Option for giving the input path for saving the result or viewing the result	-	-	Yes (LOADING option was selected) Yes (Analysis Option, SAVE as resultrepresentation) <b>-fp filepath</b>
-x -exit -t -terminate	Option for terminating the program after showing the initial analysis result	<b>true</b>	<b>false</b>	NO (Compulsory) <b>-x false</b> <b>-t false</b> <b>-exit false</b>
-f -filter	Option for providing the initial result filter values	If user haven't provided anything, then the filter values will be considered from the analysis result	<b>REQUIRED</b> <b>MAY BE REQUIRED</b> <b>MISSING</b> <b>MAYBE MISSING</b> <b>UNUSED</b>	NO (Compulsory) <b>-f filterValue1 filterValue2</b>

-dl -detaillevel	Option for providing the initial result filter values	If user haven't provided anything, then the detail values will be considered from the analysis result	Level1: <b>APP COMPONENT CLASS METHOD</b> Level2a: <b>RES_TO_RES COMPONENT STATEMENT METHOD</b> Level2b: <b>APP COMPONENT</b>	NO (Compulsory) <b>-dl APP -dl COMPONENT -dl RES_TO_RES</b> (Values are case sensitive)
-ts -testscenario	Option for providing the testscenario which will be used for not printing the result output for automated testing.	<b>false</b>	<b>true</b>	NO (Compulsory) <b>-ts true</b>
-tstat -teststat	Option for enabling test statistics in the analysis result.	<b>true</b>	<b>false</b>	NO (Compulsory) <b>-tstat false</b>

Table 3: Parameter Table : (When Analysis/ Load Option was selected)

No.	CLI Parameters	Option	Description
1	<b>-opt help</b>	Help	Help command for displaying what are all the parameters available for user.
2	<b>-l 1 -i "&lt;filepath&gt;appName.apk"</b>	Analysis	Level1, Summary Mode, View, Textual Result, No Filtering.
3	<b>-l 1 -i "&lt;filepath&gt;\appName.apk" -r save -fp "&lt;filepath&gt;applevel1.pa2"</b>	Analysis (Save Result)	Level1, Summary Mode, Save Result.

4	<b>-l 1 -i "&lt;filepath&gt;\appName1.apk" -ci "&lt;filepath&gt;\appName2.apk"</b>	Analysis	Level1, Comparison Mode, View, Textual Result, No Filtering.
5	<b>-l 1 -i "&lt;filepath&gt;\appName1.apk" -ci "&lt;filepath&gt;\appName2.pa2"</b>	Analysis	Level1, Comparison Mode, View, Textual Result, No Filtering.
6	<b>-l 1 -i "&lt;filepath&gt;\appName.apk" -v graphical</b>	Analysis	Level1, Summary Mode, View, Graphical Result.
7	<b>-l 1 -i "&lt;filepath&gt;\appName.apk" -v message</b>	Analysis	Level1, Summary Mode, View, Message Result.
8	<b>-l 1 -i "&lt;filepath&gt;\appName.apk" -exit false</b>	Analysis	Level1, Summary Mode, View, Filtering enabled.
9	<b>-l 1 -i "&lt;filepath&gt;\appName.apk" -dl APP -f REQUIRED</b>	Analysis	Level1, Summary Mode, View, Filter Initialisation.
10	<b>-opt load -fp "&lt;filepath&gt;\appName.pa2"</b>	Load	Load and View textual result.
11	<b>-opt load -fp "&lt;filepath&gt;\appName.pa2" -v graphical</b>	Load	Load and View the result Graphically.
12	<b>-opt load -fp "&lt;filepath&gt;\appName.pa2" -dl APP -f REQUIRED</b>	Load	Load, Initial filtering enabled, Textual Result.
13	<b>-opt load -fp "&lt;filepath&gt;\appName.pa2" -v message</b>	Load	Load and View result as Messages.
14	<b>-l 2a -i "&lt;filepath&gt;\appName.apk"</b>	Analysis	Level2a, Summary Mode, View , Textual Result, No Filtering.
15	<b>-l 2b -lm app -i "&lt;filepath&gt;\appName1.apk" -nn "&lt;filepath&gt;\appNameNN1.apk" "&lt;filepath&gt;\appNameNN2.pa2"</b>	Analysis	Level2b, Summary Mode, App level specific mode, View , Textual Result, No Filtering.
16	<b>-l 2b -lm all -i "&lt;filepath&gt;\appName1.apk" -nn "&lt;filepath&gt;\appNameNN1.apk" "&lt;filepath&gt;\appNameNN2.pa2"</b>	Analysis	Level2b, Summary Mode, All level specific mode, View , Textual Result, No Filtering.

17	<b>-l 2b -lm app</b> “<filepath>\appName1.apk” “<filepath>\appNameNN1.apk” ‘<filepath>\appNameNN2.apk” "<filepath>appName.pa2	<b>-i -nn -ci</b>	Analysis	Level2b, Comparison Mode, App level specific mode, View , Textual Result, No Filtering.
18	<b>-opt load</b> "<filepath>applevel2b.pa2	<b>-fp</b>	Load	Load and View textual result.

Table 4: Sample CLI Arguments/Parameters Usage

6.2.3 CLI Screenshots

In this section, you can find the screenshots for the CLI.

```
C:\Personal\Development\PG-A3-Workspace\PAndA2_Latest\build>java -jar PAndA2.jar -opt help
Usage: <main class> [options]
Options:
  -ci, -compareinput      Previous analysis file path for 'Comparison
                          Mode'. COMPULSORY if you want to use this mode.
  -dl, -detaillevel       Provide the 'Detail Level'. Available
                          options.DetailLevelLv11 ==><APP/COMPONENT/CLASS/METHOD>,DetailLevelLv12a
                          ==>
                          <RES_TO_RES/COMPONENT/STATEMENT>,DetailLevelLv12b ==> <APP/COMPONENT>
  -fp, -filepath          File path for Viewing previous result/Saving
                          current analysis result. COMPULSORY for both these
                          scenarios
  -f, -filter             Provide the 'Result Filters'. Can give more than
                          one value by giving space between them. Some filter
                          options are:Please choose any one of these
                          options.Filters
                          ==><REQUIRED/MAYBE_REQUIRED/UNUSED/MISSING/MAYBE_MISSING>
  -i, -input              Initial APK file path. COMPULSORY for all the
                          levels.
  -l, -level              Analysis Level: COMPULSORY for all the levels.
                          Please choose any one of these options.Level1
                          ==><1/LEVEL
                          1/LEVEL1/INTRA-APP-PERMISSION/INTRA-PERM/INTRA-APP-PERM>,Level2a ==> <2A/LEVEL
                          2A/LEVEL2A/INTRA-APP-INFO-FLOW/INTRA-INFO-FLOW/INTRA-IF>,Level2b ==> <2B/LEVEL
                          2B/LEVEL2B/INTER-APP-PERMISSION/INTER-APP-PERM/INTER-PERM>
  -lm, -levelmode        Analysis Level Specific Mode: COMPULSORY for
                          LEVEL2B Scenario: Please choose any one of these
                          options.<APP/ALL>.
  -nn, -nonnative         Non Native APK file path. Optional field to give
                          for LEVEL2B scenario.
  -r, -result             Result Representation Option. Available
                          options.Save ==><S/SAVE/SA>,View ==> <U/VIEW/UI>
                          Default: UIEW
  -x, -exit, -t, -terminate Terminate the program after the analysis
                          execution.
                          Default: true
  -ts, -testscenario      Whether you want the testing scenario to be
                          enabled?If so use this option so that result won't be
                          printed in the console.
                          Default: false
  -tstat, -teststats      Showing test statistics in the result.
                          Default: true
  -toopt, -opt, -option   Tool options: Please choose any one of these
                          options.Analysis ==><ANALYZE/ANA/ANALYSIS/A>,LOAD ==>
                          <LOAD/L>,HELP ==> <HELP, H, -HELP, -H, MAN, -MAN>.
                          Default: ANALYSIS
  -v, -view              Result View Option. Available options,Textual
                          ==><T/TEXT/TEXTUAL>,Graphical ==> <G, GRAPH, GRAPHICAL>,Message ==> <M, MSG,
                          MESSAGE>
                          Default: TEXTUAL
```

Figure 17: CLI - Help Option

```

Deserialized AnalysisResult...
Textual result - Intra-App Permission Usage Analysis
-----appusingapermission-----
android.permission.INTERNET <REQUIRED>
android.permission.BLUETOOTH <MAYBE REQUIRED>
android.permission.CAMERA <MISSING>
android.permission.DIAGNOSTIC <MAYBE MISSING>
android.permission.BLUETOOTH_PRIVILEGED <MAYBE MISSING>
com.android.certinstaller.INSTALL_AS_USER <MAYBE MISSING>
android.permission.MODIFY_PHONE_STATE <MAYBE MISSING>
android.permission.WRITE_CALENDAR <MAYBE MISSING>
android.permission.CAPTURE_AUDIO_OUTPUT <MAYBE MISSING>
android.permission.SIGNAL_PERSISTENT_PROCESSES <MAYBE MISSING>
com.android.cts.intent.sender.permission.SAMPLE <MAYBE MISSING>
android.permission.SHUTDOWN <MAYBE MISSING>
android.permission.DELETE_CACHE_FILES <MAYBE MISSING>
android.permission.SET_TIME_ZONE <MAYBE MISSING>
com.android.browser.permission.WRITE_HISTORY_BOOKMARKS <MAYBE MISSING>
android.permission.READ_USER_DICTIONARY <MAYBE MISSING>
android.permission.MASTER_CLEAR <MAYBE MISSING>
android.permission.WAKE_LOCK <MAYBE MISSING>
com.android.cts.permissionNotUsedWithSignature <MAYBE MISSING>
android.permission.BIND_VOICE_INTERACTION <MAYBE MISSING>
android.permission.DISABLE_KEYGUARD <MAYBE MISSING>
android.permission.BIND_NOTIFICATION_LISTENER_SERVICE <MAYBE MISSING>
android.permission.CALL_PRIVILEGED <MAYBE MISSING>
android.permission.GET_PACKAGE_SIZE <MAYBE MISSING>
com.android.permission.WHITELIST_BLUETOOTH_DEVICE <MAYBE MISSING>
android.permission.CAPTURE_VIDEO_OUTPUT <MAYBE MISSING>
com.android.alarm.permission.SET_ALARM <MAYBE MISSING>
android.permission.SET_WALLPAPER_HINTS <MAYBE MISSING>
android.permission.CHANGE_WIFI_STATE <MAYBE MISSING>
com.android.launcher.permission.PRELOAD_WORKSPACE <MAYBE MISSING>
android.permission.GET_TASKS <MAYBE MISSING>
android.permission.SET_WALLPAPER <MAYBE MISSING>
android.permission.SET_TIME <MAYBE MISSING>
com.android.providers.tv.permission.READ_EPG_DATA <MAYBE MISSING>
android.permission.BIND_PRINT_SERVICE <MAYBE MISSING>
android.permission.READ_CONTACTS <MAYBE MISSING>
android.permission.READ_LOGS <MAYBE MISSING>
android.permission.CAPTURE_SECURE_VIDEO_OUTPUT <MAYBE MISSING>
android.permission.READ_SMS <MAYBE MISSING>
android.permission.READ_SYNC_SETTINGS <MAYBE MISSING>
android.permission.BROADCAST_SMS <MAYBE MISSING>
android.permission.AUTHENTICATE_ACCOUNTS <MAYBE MISSING>
android.permission.READ_CELL_BROADCASTS <MAYBE MISSING>
android.permission.BLUETOOTH_ADMIN <MAYBE MISSING>
android.permission.CONTROL_LOCATION_UPDATES <MAYBE MISSING>
android.permission.WRITE_GSERVICES <MAYBE MISSING>
android.permission.BODY_SENSORS <MAYBE MISSING>
android.permission.READ_PROFILE <MAYBE MISSING>
android.permission.NFC <MAYBE MISSING>
android.permission.READ_FRAME_BUFFER <MAYBE MISSING>
android.permission.RECEIVE_BOOT_COMPLETED <MAYBE MISSING>

```

Figure 18: CLI - Load - Textual Result - Page1

```

android.permission.FACTORY_TEST <MAYBE MISSING>
android.permission.CHANGE_NETWORK_STATE <MAYBE MISSING>
android.os.cts.permission.TEST_DENIED <MAYBE MISSING>
android.permission.MODIFY_AUDIO_SETTINGS <MAYBE MISSING>
android.permission.READ_EXTERNAL_STORAGE <MAYBE MISSING>
android.permission.ACCESS_LOCATION_EXTRA_COMMANDS <MAYBE MISSING>
android.permission.READ_PHONE_STATE <MAYBE MISSING>
android.permission.WRITE_SETTINGS <MAYBE MISSING>
android.permission.BIND_DEVICE_ADMIN <MAYBE MISSING>
com.android.launcher.permission.WRITE_SETTINGS <MAYBE MISSING>
INFO 2016-03-31 10:46:51.769 [main] de.upb.pga3.panda2.client.cmdline.HtmlParser:parse(160): Result was parsed successfully
Would you like to filter the result? Please type Y/N

```

Figure 19: CLI - Load - Textual Result - Page2

```

[main] de.upb.pga3.panda2.client.cmdline.HtmlParser:parse(160): Result was parsed successfully
[main] de.upb.pga3.panda2.main.ApplicationEntryPoint:main(58): Program is terminated.

```

Figure 20: CLI - Load - Textual Result - Page3

```

Deserialized AnalysisResult...
Message:1
---Message Type--- ERROR
---Message Body--- The analyzed App contains one or more missing permissions. This should be considered as security
---Message Title--- MISSING Permission
Message:1
---Message Type--- WARNING
---Message Body--- The analyzed App contains one or more unused permissions. Permissions are declared in the Andro
---Message Title--- UNUSED Permission
Message:2
---Message Type--- WARNING
---Message Body--- The analyzed App contains one or more maybe missing permissions. There might be a cooperation b
---Message Title--- MAYBE MISSING Permission
Message:3
---Message Type--- WARNING
---Message Body--- The analyzed App contains one or more maybe required permissions. There might be a cooperation I
---Message Title--- MAYBE REQUIRED Permission
Message:1
---Message Type--- SUGGESTION
---Message Body--- There are some statements contained in the source code of this Application, that's permission us
In this case it is suggested to run a Level 2b analysis in order to get a more detailed result.
---Message Title--- Suggestion: Deeper analysis
INFO 2016-03-31 10:42:33.958 [main] de.upb.pga3.panda2.main.ApplicationEntryPoint:main(58): Program is terminated.

```

Figure 21: CLI - Load - Message Result

```
java -jar PAndA2.jar -opt load -fp "C:\Personal\pg-a3-latest\trunk\implementation\PAndA2\test_resources\AnaResult1.pa2" -x false
```

Figure 22: CLI - Result Filter - Page 1

```
Deserialized AnalysisResult...
Textual result - Intra-App Permission Usage Analysis
-----appusingapermission-----
android.permission.INTERNET <REQUIRED>
android.permission.BLUETOOTH <MAYBE REQUIRED>
android.permission.CAMERA <MISSING>
android.permission.DIAGNOSTIC <MAYBE MISSING>
android.permission.BLUETOOTH_PRIVILEGED <MAYBE MISSING>
com.android.certinstaller.INSTALL_AS_USER <MAYBE MISSING>
android.permission.MODIFY_PHONE_STATE <MAYBE MISSING>
android.permission.WRITE_CALENDAR <MAYBE MISSING>
android.permission.CAPTURE_AUDIO_OUTPUT <MAYBE MISSING>
android.permission.SIGNAL_PERSISTENT_PROCESSES <MAYBE MISSING>
com.android.cts.intent.sender.permission.SAMPLE <MAYBE MISSING>
android.permission.SHUTDOWN <MAYBE MISSING>
android.permission.DELETE_CACHE_FILES <MAYBE MISSING>
android.permission.SET_TIME_ZONE <MAYBE MISSING>
com.android.browser.permission.WRITE_HISTORY_BOOKMARKS <MAYBE MISSING>
android.permission.READ_USER_DICTIONARY <MAYBE MISSING>
android.permission.MASTER_CLEAR <MAYBE MISSING>
android.permission.WAKE_LOCK <MAYBE MISSING>
com.android.cts.permissionNotUsedWithSignature <MAYBE MISSING>
android.permission.BIND_VOICE_INTERACTION <MAYBE MISSING>
```

Figure 23: CLI - Result Filter - Page 2

```

Would you like to filter the result? Please type Y/N
Y
---AVAILABLE DETAIL LEVELS---
APP
COMPONENT
CLASS
METHOD

---AVAILABLE RESULT FILTERS---
Expandable tree
REQUIRED
MAYBE REQUIRED
UNUSED
MISSING
MAYBE MISSING
Permission: android.permission.INTERNET
Permission: android.permission.BLUETOOTH
Permission: android.permission.CAMERA
Permission: android.permission.DIAGNOSTIC
Permission: android.permission.BLUETOOTH_PRIVILEGED
Permission: com.android.certinstaller.INSTALL_AS_USER
Permission: android.permission.MODIFY_PHONE_STATE
Permission: android.permission.WRITE_CALENDAR
Permission: android.permission.CAPTURE_AUDIO_OUTPUT
Permission: android.permission.SIGNAL_PERSISTENT_PROCESSES
Permission: com.android.cts.intent.sender.permission.SAMPLE
Permission: android.permission.SHUTDOWN
Permission: android.permission.DELETE_CACHE_FILES
Permission: android.permission.SET_TIME_ZONE
Permission: com.android.browser.permission.WRITE_HISTORY_BOOKMARK
Permission: android.permission.READ_USER_DICTIONARY
Permission: android.permission.MASTER_CLEAR
Permission: android.permission.WAKE_LOCK
Permission: com.android.cts.permissionNotUsedWithSignature
Permission: android.permission.BIND_VOICE_INTERACTION
Permission: android.permission.DISABLE_KEYGUARD
Permission: android.permission.BIND_NOTIFICATION_LISTENER_SERVICE
Permission: android.permission.CALL_PRIVILEGED
Permission: android.permission.GET_PACKAGE_SIZE
Permission: com.android.permission.WHITELIST_BLUETOOTH_DEVICE
Permission: android.permission.CAPTURE_VIDEO_OUTPUT
Permission: com.android.alarm.permission.SET_ALARM
Permission: android.permission.SET_WALLPAPER_HINTS
Permission: android.permission.CHANGE_WIFI_STATE
Permission: com.android.launcher.permission.PRELOAD_WORKSPACE
Permission: android.permission.GET_TASKS
Permission: android.permission.SET_WALLPAPER
Permission: android.permission.SET_TIME
Permission: com.android.providers.tv.permission.READ_EPG_DATA
Permission: android.permission.BIND_PRINT_SERVICE
Permission: android.permission.READ_CONTACTS
Permission: android.permission.READ_LOGS
Permission: android.permission.CAPTURE_SECURE_VIDEO_OUTPUT
Permission: android.permission.READ_SMS

```

Figure 24: CLI - Result Filter - Page 3

```

Select your desired level:
APP
Select your desired filter:
REQUIRED

Textual result - Intra-App Permission Usage Analysis
-----appusingapermission-----
android.permission.INTERNET <REQUIRED>

```

Figure 25: CLI - Result Filter - Page 4

```

Would you like to filter the result? Please type Y/N
N
INFO 2016-03-31 12:40:47,402 [main] de.upb.pga3.panda2.main.ApplicationEntryPoint:main(58): Program is terminated.

```

Figure 26: CLI - Result Filter - Page 5

```

App's name: testcase3
Source(s)-----Paths (to sinks)-----
android.permission.READ_PHONE_STATE <SOURCE>-----android.permission.WRITE_SMS <T
ARGET>
android.permission.READ_PHONE_STATE <SOURCE>-----android.permission.SEND_SMS <TA
RGET>

INFO 2016-03-31 17:24:49,545 [main] de.upb.pga3.panda2.client.cmdline.HtmlParse
r:parse(160): Result was parsed successfully
INFO 2016-03-31 17:24:49,545 [main] de.upb.pga3.panda2.main.ApplicationEntryPoi
nt:main(58): Program is terminated.

```

Figure 27: CLI - Analysis - Level2a

```

AnalyzerLvl2a:analyze(148): Analyzer finished (Source&Sink - Intra App - Level
2a)
INFO 2016-03-31 17:29:29,452 [main] de.upb.pga3.panda2.core.AnalysisRunner:anal
yze(73): Finished analysis
INFO 2016-03-31 17:29:29,467 [main] de.upb.pga3.panda2.core.AnalysisRunner:anal
yze(74): Time needed for analysis: PT3.059S
INFO 2016-03-31 17:29:29,467 [main] de.upb.pga3.panda2.core.AnalysisRunner:anal
yze(75): Max. memory needed for analysis: 12MB
Successfully saved the result.
INFO 2016-03-31 17:29:30,896 [main] de.upb.pga3.panda2.main.ApplicationEntryPoi
nt:main(58): Program is terminated.

```

Figure 28: CLI - Analysis - Level2a - Save

## 7 User Story

### 7.1 GUI

#### 7.1.1 Problem

To find out missing permissions in an android application for example *AllCasesLevel1App.apk*, and if the application is trustworthy to use.

#### 7.1.2 Description

User needs to run *PermissionUsage(IntraApp – Level1Analysis)* on the .apk file using PAndA<sup>2</sup> tool. The result of analysis will tell the user about the missing permissions and whether the application is trustworthy or not.

#### 7.1.3 Steps

This section will describe the steps or sequence of actions to be carried out to achieve the goal. At first, we need to start the tool PAndA<sup>2</sup> and then starting a fresh Analysis. When choosing analysis level, user needs to choose *PermissionUsage(IntraApp – Level1)* from the drop down list as shown in fig. 29 and then click on *Next*.



Figure 29: US Input-part1

In the next step, the user needs to give the application path as input shown in fig. 30. In this case, users can leave all other things blank and clicking on *Finish* to finalize the parameters and start analysis.

The tool will take its time to analyse the application according to the parameters given and will return user results in textual form as shown in fig. 31 and graphical form as shown in fig. 32. The user can look up results and can easily come to a conclusion.

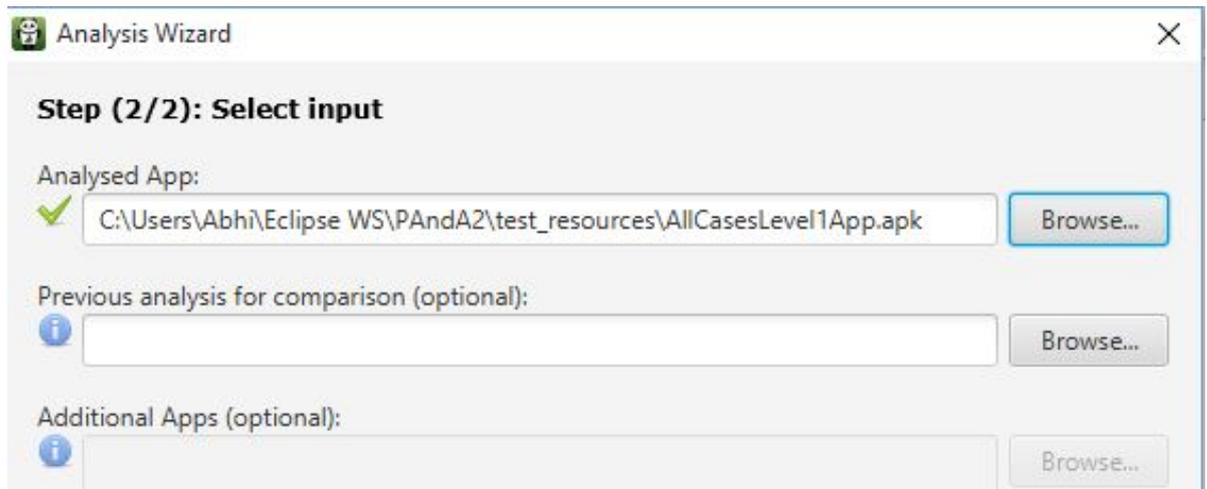


Figure 30: US Input-part2

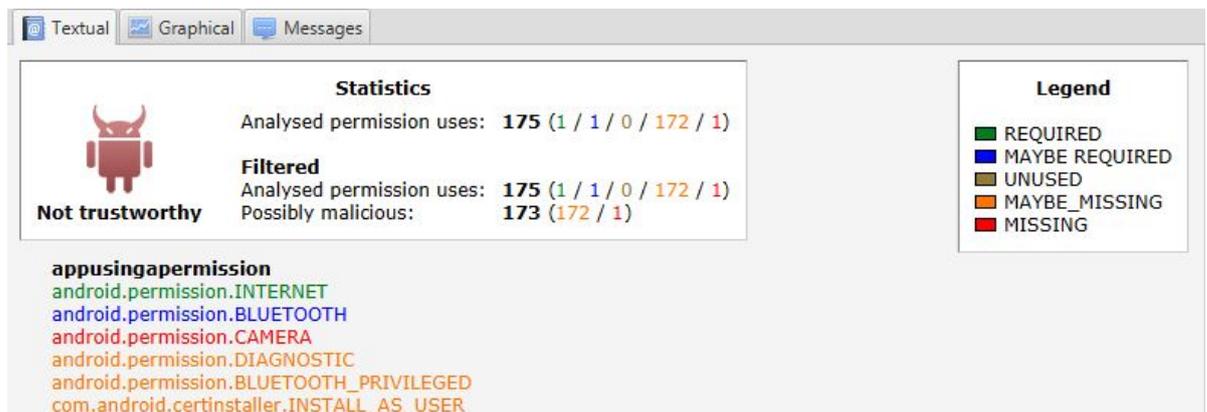


Figure 31: US Result-part1

#### 7.1.4 Result

The analysis result as shown in fig. 31 shows that *android.permission.CAMERA* is missing (Check Legend on the right hand side) and the application file is *NotTrustworthy*

## 7.2 CLI

### 7.2.1 Problem

Consider the same problem, which was described in the previous section 7.1

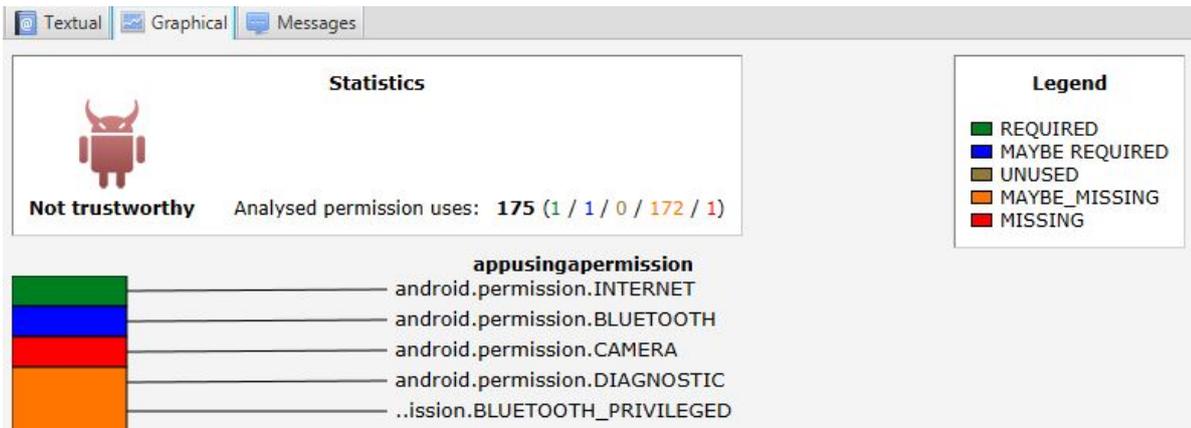


Figure 32: US Result-part2

### 7.2.2 Description

Consider the same problem description, which was described in the previous section 7.1

### 7.2.3 Steps

Similar to GUI, for running this use case in our PAndA<sup>2</sup> tool, we need to use the following steps,

1. Open the command prompt (Windows) or terminal (Linux) for accessing our PAndA<sup>2</sup> tool through CLI (Refer figure 33).
2. Go to the related location in the command prompt (or) terminal where our PAndA<sup>2</sup> tool jar was located (Refer figure 33).
3. Type the related command line parameter for starting the analysis for this scenario (Refer figure 34).
4. Result can be viewed in the command prompt (or) terminal once the analysis was executed successfully (Refer section 7.2.4).

### 7.2.4 Result

Similar to GUI, the analysis result shown in figure 36 represents that *android.permission.CAMERA* is missing and the application file is *NotTrustworthy*.

```
Microsoft Windows [Version 6.3.9600]
(c) 2013 Microsoft Corporation. All rights reserved.

C:\Users\Sriram>cd C:\Personal\Development\PG-A3-Workspace\PAndA2_Latest\build
C:\Personal\Development\PG-A3-Workspace\PAndA2_Latest\build>
```

Figure 33: User Story CLI - Command Prompt

```
java -jar PAndA2.jar -l 1 -i "C:\Personal\pg-a3-latest\trunk\implementation\PAndA2\test_resources\AllCasesLevel1app.apk"
```

Figure 34: User Story CLI - parameters

```
[main] de.upb.pga3.panda2.core.AnalysisRunner:analyze(36): Running analysis consisting of 1 steps
[main] de.upb.pga3.panda2.utilities.MemoryUsageMonitor:setupMonitoring(98): Set up memory usage monitoring
[main] de.upb.pga3.panda2.extension.Enhancer:enhance(52): Enhancer started (C:\Personal\pg-a3-latest\trunk\implementation\PAndA2\test_resources\AllCasesLevel1app.apk)
[Service Thread] de.upb.pga3.panda2.utilities.MemoryUsageMonitor:logMem(148): Used Heapspace: 8MB
[Service Thread] de.upb.pga3.panda2.utilities.MemoryUsageMonitor:logMem(148): Used Heapspace: 88MB
[main] de.upb.pga3.panda2.core.SootAdapter:run(156): Run WJIP phase
[main] de.upb.pga3.panda2.extension.Enhancer:enhance(126): Enhancer finished (C:\Personal\pg-a3-latest\trunk\implementation\PAndA2\test_resources\AllCasesLevel1app.apk)
[main] de.upb.pga3.panda2.extension.lvl1.graphgenerator.GraphGeneratorLvl1:generateGraph(25): Graph generated
[main] de.upb.pga3.panda2.extension.lvl1.graphgenerator.GraphGeneratorLvl1:generateGraph(30): Graph generated
[main] de.upb.pga3.panda2.extension.lvl1.analyzer.AnalyzerLvl1:analyze(24): Analyzer started (Perm)
[main] de.upb.pga3.panda2.extension.lvl1.analyzer.AnalyzerLvl1:analyze(32): Analyzer finished (Perm)
[main] de.upb.pga3.panda2.core.AnalysisRunner:analyze(73): Finished analysis
[main] de.upb.pga3.panda2.core.AnalysisRunner:analyze(74): Time needed for analysis: PT5.328S
[main] de.upb.pga3.panda2.core.AnalysisRunner:analyze(75): Max. memory needed for analysis: 88MB
```

Figure 35: User Story CLI - Textual Result - Page 1

```
Textual result - Intra-App Permission Usage Analysis
-----appusingapermission-----
android.permission.INTERNET <REQUIRED>
android.permission.BLUETOOTH <MAYBE REQUIRED>
android.permission.CAMERA <MISSING>
android.permission.DIAGNOSTIC <MAYBE MISSING>
android.permission.BLUETOOTH_PRIVILEGED <MAYBE MISSING>
com.android.certinstaller.INSTALL_AS_USER <MAYBE MISSING>
android.permission.MODIFY_PHONE_STATE <MAYBE MISSING>
android.permission.WRITE_CALENDAR <MAYBE MISSING>
android.permission.CAPTURE_AUDIO_OUTPUT <MAYBE MISSING>
android.permission.SIGNAL_PERSISTENT_PROCESSES <MAYBE MISSING>
com.android.cts.intent.sender.permission.SAMPLE <MAYBE MISSING>
android.permission.SHUTDOWN <MAYBE MISSING>
android.permission.DELETE_CACHE_FILES <MAYBE MISSING>
android.permission.SET_TIME_ZONE <MAYBE MISSING>
com.android.browser.permission.WRITE_HISTORY_BOOKMARKS <MAYBE MISSING>
android.permission.READ_USER_DICTIONARY <MAYBE MISSING>
android.permission.MASTER_CLEAR <MAYBE MISSING>
android.permission.WAKE_LOCK <MAYBE MISSING>
com.android.cts.permissionNotUsedWithSignature <MAYBE MISSING>
android.permission.BIND_VOICE_INTERACTION <MAYBE MISSING>
android.permission.DISABLE_KEYGUARD <MAYBE MISSING>
android.permission.BIND_NOTIFICATION_LISTENER_SERVICE <MAYBE MISSING>
android.permission.CALL_PRIVILEGED <MAYBE MISSING>
android.permission.GET_PACKAGE_SIZE <MAYBE MISSING>
com.android.permission.WHITELIST_BLUETOOTH_DEVICE <MAYBE MISSING>
android.permission.CAPTURE_VIDEO_OUTPUT <MAYBE MISSING>
com.android.alarm.permission.SET_ALARM <MAYBE MISSING>
android.permission.SET_WALLPAPER_HINTS <MAYBE MISSING>
android.permission.CHANGE_WIFI_STATE <MAYBE MISSING>
com.android.launcher.permission.PRELOAD_WORKSPACE <MAYBE MISSING>
android.permission.GET_TASKS <MAYBE MISSING>
android.permission.SET_WALLPAPER <MAYBE MISSING>
android.permission.SET_TIME <MAYBE MISSING>
com.android.providers.tv.permission.READ_EPG_DATA <MAYBE MISSING>
android.permission.BIND_PRINT_SERVICE <MAYBE MISSING>
android.permission.READ_CONTACTS <MAYBE MISSING>
android.permission.READ_LOGS <MAYBE MISSING>
android.permission.CAPTURE_SECURE_VIDEO_OUTPUT <MAYBE MISSING>
android.permission.READ_SMS <MAYBE MISSING>
android.permission.READ_SYNC_SETTINGS <MAYBE MISSING>
android.permission.BROADCAST_SMS <MAYBE MISSING>
```

Figure 36: User Story CLI - Textual Result - Page2

```

android.permission.AUTHENTICATE_ACCOUNTS <MAYBE MISSING>
android.permission.READ_CELL_BROADCASTS <MAYBE MISSING>
android.permission.BLUETOOTH_ADMIN <MAYBE MISSING>
android.permission.CONTROL_LOCATION_UPDATES <MAYBE MISSING>
android.permission.WRITE_GSERVICES <MAYBE MISSING>
android.permission.BODY_SENSORS <MAYBE MISSING>
android.permission.READ_PROFILE <MAYBE MISSING>
android.permission.NFC <MAYBE MISSING>
android.permission.READ_FRAME_BUFFER <MAYBE MISSING>
android.permission.RECEIVE_BOOT_COMPLETED <MAYBE MISSING>
android.permission.CHANGE_COMPONENT_ENABLED_STATE <MAYBE MISSING>
android.permission.ACCESS_FINE_LOCATION <MAYBE MISSING>
com.android.voicemail.permission.ADD_VOICEMAIL <MAYBE MISSING>
com.android.launcher.permission.UNINSTALL_SHORTCUT <MAYBE MISSING>
android.permission.LOCATION_HARDWARE <MAYBE MISSING>
android.permission.ACCESS_CHECKIN_PROPERTIES <MAYBE MISSING>
com.android.launcher.permission.INSTALL_SHORTCUT <MAYBE MISSING>
android.permission.MOUNT_FORMAT_FILESYSTEMS <MAYBE MISSING>
android.permission.SEND_RESPOND_VIA_MESSAGE <MAYBE MISSING>
com.android.cts.permissionNormal <MAYBE MISSING>
android.permission.SEND_SMS <MAYBE MISSING>
android.permission.USE_SIP <MAYBE MISSING>
android.permission.WRITE_SMS <MAYBE MISSING>
com.android.launcher.permission.READ_SETTINGS <MAYBE MISSING>
android.permission.CHANGE_CONFIGURATION <MAYBE MISSING>
android.permission.STATUS_BAR <MAYBE MISSING>
android.permission.VIBRATE <MAYBE MISSING>
com.android.frameworks.coretests.permission.TEST_DENIED <MAYBE MISSING>
android.permission.REORDER_TASKS <MAYBE MISSING>
android.permission.RECEIVE_MMS <MAYBE MISSING>
android.permission.BIND_ACCESSIBILITY_SERVICE <MAYBE MISSING>
com.android.launcher3.permission.READ_SETTINGS <MAYBE MISSING>
android.permission.WRITE_SYNC_SETTINGS <MAYBE MISSING>
android.permission.KILL_BACKGROUND_PROCESSES <MAYBE MISSING>
android.permission.RESTART_PACKAGES <MAYBE MISSING>
android.permission.READ_CALL_LOG <MAYBE MISSING>
android.permission.BIND_TRUST_AGENT <MAYBE MISSING>
grant-uri-permission <MAYBE MISSING>
android.permission.ACCOUNT_MANAGER <MAYBE MISSING>
com.android.frameworks.coretests.permission.TEST_GRANTED <MAYBE MISSING>
android.permission.ACCESS MOCK_LOCATION <MAYBE MISSING>
android.permission.GLOBAL_SEARCH <MAYBE MISSING>
android.permission.TRANSMIT_IR <MAYBE MISSING>
com.android.voicemail.permission.WRITE_VOICEMAIL <MAYBE MISSING>
android.permission.WRITE_USER_DICTIONARY <MAYBE MISSING>
android.permission.BROADCAST_WAP_PUSH <MAYBE MISSING>
android.permission.MEDIA_CONTENT_CONTROL <MAYBE MISSING>
android.permission.READ_CALENDAR <MAYBE MISSING>
android.permission.BIND_CARRIER_MESSAGING_SERVICE <MAYBE MISSING>
android.permission.MANAGE_DOCUMENTS <MAYBE MISSING>
android.permission.INSTALL_PACKAGES <MAYBE MISSING>
android.permission.BIND_INCALL_SERVICE <MAYBE MISSING>
com.android.browser.permission.READ_HISTORY_BOOKMARKS <MAYBE MISSING>
android.permission.REBOOT <MAYBE MISSING>
android.permission.SET_ALWAYS_FINISH <MAYBE MISSING>
android.permission.SET_PREFERRED_APPLICATIONS <MAYBE MISSING>
com.android.gallery3d.filtershow.permission.READ <MAYBE MISSING>
android.permission.BIND_TV_INPUT <MAYBE MISSING>
android.permission.ACCESS_COARSE_LOCATION <MAYBE MISSING>

```

Figure 37: User Story CLI - Textual Result - Page3

```

android.permission.SET_PROCESS_LIMIT <MAYBE MISSING>
android.permission.PROCESS_OUTGOING_CALLS <MAYBE MISSING>
android.permission.WRITE_SECURE_SETTINGS <MAYBE MISSING>
com.android.email.permission.READ_ATTACHMENT <MAYBE MISSING>
android.permission.BIND_CONNECTION_SERVICE <MAYBE MISSING>
android.permission.ACCESS_WIFI_STATE <MAYBE MISSING>
android.permission.MANAGE_ACCOUNTS <MAYBE MISSING>
com.android.providers.tv.permission.WRITE_EPG_DATA <MAYBE MISSING>
android.permission.WRITE_APN_SETTINGS <MAYBE MISSING>
android.permission.CLEAR_APP_CACHE <MAYBE MISSING>
android.permission.BIND_PRINT_SPOOLER_SERVICE <MAYBE MISSING>
com.android.voicemail.permission.READ_VOICEMAIL <MAYBE MISSING>
android.permission.CHANGE_WIFI_MULTICAST_STATE <MAYBE MISSING>
com.android.smspush.WAPPUSH_MANAGER_BIND <MAYBE MISSING>
android.permission.BIND_UPN_SERVICE <MAYBE MISSING>
android.permission.ACCESS_ALL_DOWNLOADS <MAYBE MISSING>
android.permission.MOUNT_UNMOUNT_FILESYSTEMS <MAYBE MISSING>
android.permission.RECORD_AUDIO <MAYBE MISSING>
android.permission.BROADCAST_PACKAGE_REMOVED <MAYBE MISSING>
android.permission.BROADCAST_STICKY <MAYBE MISSING>
android.permission.READ_SYNC_STATS <MAYBE MISSING>
android.permission.INSTALL_LOCATION_PROVIDER <MAYBE MISSING>
android.permission.MMS_SEND_OUTBOX_MSG <MAYBE MISSING>
android.permission.BIND_DREAM_SERVICE <MAYBE MISSING>
android.app.cts.permission.TEST_DENIED <MAYBE MISSING>
android.permission.UPDATE_DEVICE_STATS <MAYBE MISSING>
android.permission.READ_INPUT_STATE <MAYBE MISSING>
android.permission.CALL_PHONE <MAYBE MISSING>
android.permission.FLASHLIGHT <MAYBE MISSING>
android.permission.GET_ACCOUNTS <MAYBE MISSING>
android.permission.SET_DEBUG_APP <MAYBE MISSING>
android.os.cts.permission.TEST_GRANTED <MAYBE MISSING>
android.permission.BIND_WALLPAPER <MAYBE MISSING>
android.permission.EXPAND_STATUS_BAR <MAYBE MISSING>
android.permission.SYSTEM_ALERT_WINDOW <MAYBE MISSING>
android.permission.ACCESS_BLUETOOTH_SHARE <MAYBE MISSING>
android.app.cts.permission.TEST_GRANTED <MAYBE MISSING>
android.permission.BIND_INPUT_METHOD <MAYBE MISSING>
android.permission.WRITE_EXTERNAL_STORAGE <MAYBE MISSING>
android.permission.BIND_REMOTEVIEWS <MAYBE MISSING>
com.google.android.c2dm.permission.SEND <MAYBE MISSING>
android.permission.BIND_NFC_SERVICE <MAYBE MISSING>
android.permission.SET_ANIMATION_SCALE <MAYBE MISSING>
android.permission.PERSISTENT_ACTIVITY <MAYBE MISSING>
android.permission.ACCESS_NETWORK_STATE <MAYBE MISSING>
com.android.browser.permission.PRELOAD <MAYBE MISSING>
android.permission.WRITE_CONTACTS <MAYBE MISSING>
android.permission.BATTERY_STATS <MAYBE MISSING>
com.android.gallery3d.permission.GALLERY_PROVIDER <MAYBE MISSING>
android.permission.DELETE_PACKAGES <MAYBE MISSING>
android.permission.DUMP <MAYBE MISSING>
android.permission.RECEIVE_SMS <MAYBE MISSING>
android.permission.BIND_TEXT_SERVICE <MAYBE MISSING>
android.permission.RECEIVE_WAP_PUSH <MAYBE MISSING>
android.permission.CONFIRM_FULL_BACKUP <MAYBE MISSING>
com.android.gallery3d.filtershow.permission.WRITE <MAYBE MISSING>
android.permission.PERFORM_CDMA_PROVISIONING <MAYBE MISSING>
android.permission.WRITE_CALL_LOG <MAYBE MISSING>
com.android.email.permission.ACCESS_PROVIDER <MAYBE MISSING>

```

Figure 38: User Story CLI - Textual Result - Page4

```
android.permission.WRITE_CONTACTS <MAYBE MISSING>
android.permission.BATTERY_STATS <MAYBE MISSING>
com.android.gallery3d.permission.GALLERY_PROVIDER <MAYBE MISSING>
android.permission.DELETE_PACKAGES <MAYBE MISSING>
android.permission.DUMP <MAYBE MISSING>
android.permission.RECEIVE_SMS <MAYBE MISSING>
android.permission.BIND_TEXT_SERVICE <MAYBE MISSING>
android.permission.RECEIVE_WAP_PUSH <MAYBE MISSING>
android.permission.CONFIRM_FULL_BACKUP <MAYBE MISSING>
com.android.gallery3d.filtershow.permission.WRITE <MAYBE MISSING>
android.permission.PERFORM_CDMA_PROVISIONING <MAYBE MISSING>
android.permission.WRITE_CALL_LOG <MAYBE MISSING>
com.android.email.permission.ACCESS_PROVIDER <MAYBE MISSING>
com.android.cts.permissionWithSignature <MAYBE MISSING>
android.permission.BIND_REMOTE_DISPLAY <MAYBE MISSING>
android.permission.READ_SEARCH_INDEXABLES <MAYBE MISSING>
android.permission.BIND_APPWIDGET <MAYBE MISSING>
com.android.launcher3.permission.WRITE_SETTINGS <MAYBE MISSING>
android.permission.USE_CREDENTIALS <MAYBE MISSING>
android.permission.FACTORY_TEST <MAYBE MISSING>
android.permission.CHANGE_NETWORK_STATE <MAYBE MISSING>
android.os.cts.permission.TEST_DENIED <MAYBE MISSING>
android.permission.MODIFY_AUDIO_SETTINGS <MAYBE MISSING>
android.permission.READ_EXTERNAL_STORAGE <MAYBE MISSING>
android.permission.ACCESS_LOCATION_EXTRA_COMMANDS <MAYBE MISSING>
android.permission.READ_PHONE_STATE <MAYBE MISSING>
android.permission.WRITE_SETTINGS <MAYBE MISSING>
android.permission.BIND_DEVICE_ADMIN <MAYBE MISSING>
com.android.launcher.permission.WRITE_SETTINGS <MAYBE MISSING>
```

Figure 39: User Story CLI - Textual Result - Page5

```
[main] de.upb.pga3.panda2.client.cmdline.HtmlParser:parse(160): Result was parsed successfully
[main] de.upb.pga3.panda2.main.ApplicationEntryPoint:main(58): Program is terminated.
```

Figure 40: User Story CLI - Textual Result - Page6

## 8 Question and Answers

### 1. How many types of analysis can a user perform with PAndA<sup>2</sup> ?

User can perform three type of analysis on .apk files, they are-

- Permission Usage (Intra App- Level 1)
- Information Flow (Intra App- Level 2a)
- Permission Usage (Inter App- Level 2b)

### 2. Can .apk file be compared with other .apk file?

Yes, .apk file can also be given as comparison input for all the analysis.

### 3. How many types of analysis results can user view with PAndA<sup>2</sup> ?

User having option to view the analysis result in two representations, they are.

- Textual
- Graphical

and one helping view *MessagesTab* to view suggestions, errors and warnings encountered during analysis.

### 4. Whether analysis can be performed through Command Line?

yes, it can be performed with the help of command line paramters for starting our PAndA<sup>2</sup> tool using CLI with the help of command prompt (Windows) or terminal (Linux). For more about using CLI, please refer 6.2.

### 5. Where can user find document related to PAndA<sup>2</sup> ?

User can find the documentation under *Help* menu on the Menubar.

### 6. Can Analysis result be compared to a saved result of different analysis in PAndA<sup>2</sup> ?

No, comparison should be done within same level of analysis.

### 7. How to extend PAndA<sup>2</sup> ?

#### a) How to add a new analysis?

1. Develop a new class that implements the `AnalysisProcedure` interface or reuse our `A3AnalysisProcedure` if you want to use the `Enhancer-GraphGenerator-Analyzer` structure.
2. Create a factory that suits the new analysis by implementing the `AnalysisFactory` interface. This factory has to return an `Analysis` object that uses the new `AnalysisProcedure` implementation.
3. Edit the `Client` in order to start the new analysis level. In case of the original PAndA<sup>2</sup> `Client` only the class `AnalysisRegistry` has to be adapted.

#### b) How to add a new Client?

1. Build your own `Client` (User Interface). Feel free to use any sort of library or framework.
2. Use a class implementing the `AnalysisFactory` interface in order to create an `Analysis`.
3. Then call the `AnalysisRunner` to start the `Analysis` created in the last step.
4. OPTIONAL: If you run the analysis asynchronously, you have to implement the interface `AsyncAnalysisResult` to receive the `AnalysisResult`.

c) **How to switch to a new Android API?**

1. Checkout the Android source code of the selected API level.
2. Build the Android source code.
3. Download and run PScout on the created build.
4. PScout will create several files (*allmappings*, *contentproviderfieldpermission*, *contentproviderpermission*, *intentpermission*, *publishedapimapping*). All of them have to be copied into the *data* folder of PAndA<sup>2</sup>. (All steps until here require a lot of time. On an ordinary desktop computer from 2015 it takes about 4 days.)
5. OPTIONAL: Update the *apilevel* file in the *data* folder of PAndA<sup>2</sup>. It should simply contain the current API version number. (Otherwise PAndA<sup>2</sup> will not know the correct version number.)
6. OPTIONAL: Add/Remove permissions from the list, stored in the *listofallpermissions* file, that have been added or removed in contrast to API 22. (This step is optional, because the stored list can be extended during runtime. Nevertheless removed permissions will still be expected as being available. The only thing the generated list might lack are permissions that exist but are not checked by the Android system at all.)

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