How Reliable is My Wearable: A Fuzz Testing-based Study

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Outline

- Motivation and Background
- Android and Android Wear Overview
- Approach to Evaluate Reliability: Qui-Gon Jinn (QGJ)
- Evaluation
- Conclusion and Lessons Learned

Motivation

- Reliability of Android is well explored but wearables come with a new set of challenges
- Wearable devices are **sensor rich**
- Devices have **limited resources**
  - Display area, computing power, volatile and non-volatile memory, battery size
- **More background work** (services) than foreground work (activities)
- **Communication pattern** where many apps are controlled by a mobile counterpart
- A large use-case is monitoring, accumulation and dissemination of **health and fitness** data

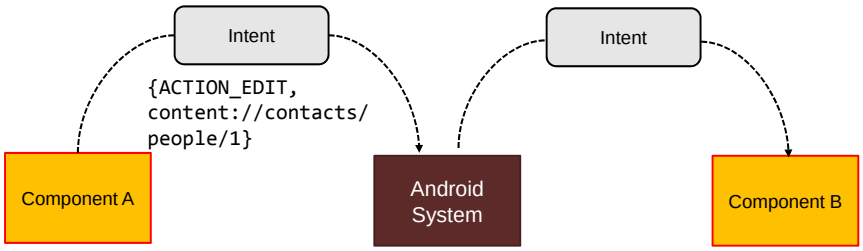
Android Wear (AW)

- The most popular wearable OS (released in 2014): We use 2017 release
- User Interface (UI) is designed **to require minimal human interaction** (micro transactions)
- Applications are more **services driven**, in contrast to Android applications, which usually have rich GUI
- AW makes heavy use of sensors
  - Common use case of fitness and health monitoring

androidwear

Android IPC: Background

- Android programming model is based on passing **Intent** messages among the components.
- An **Intent** describes an operation to be performed and data to perform it
  - The basic information includes: Action, Category, Data, Component, and Extras
  - Types: Explicit and Implicit



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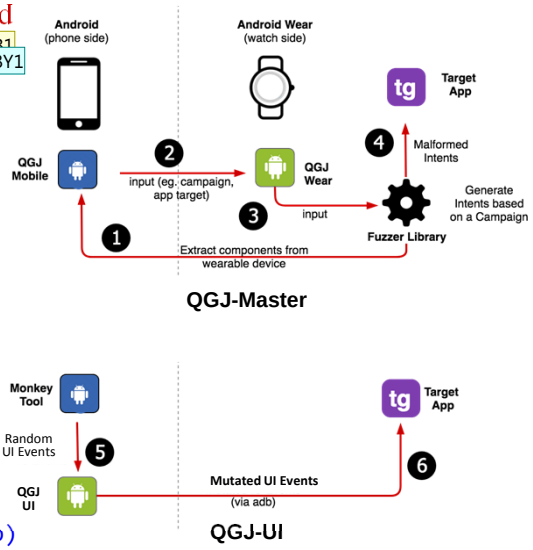
Approach to Evaluate Reliability

- Evaluate robustness of Android Wear apps by injecting fuzzed Intents
- Discover vulnerabilities through random and mutated Intents
- Propose recommendations for improving the robustness of Android Wear apps

Qui-Gon Jinn (QGJ)

- QGJ is a user-level app and does not require any system-level permission
- QGJ-Master
  - Generates intents based on Fuzz Injection Campaigns (FIC)
  - Supports fuzz injection of Activities and Services components
- QGJ-UI
  - Mutates semi-valid and random UI events
  - Injects UI events using Android Debug Bridge (adb)



Slide 8

SB1 Is this true? No permission or no system-level permission?
Saurabh Bagchi, 6/24/2018

EBY1 QGJ does not require any additional permission to fuzz applications. Just the basic permission needed by an app
Edgardo Barsallo Yi, 6/25/2018

Fuzz Injection Campaigns

- Semi-valid Action and Data

{act=ACTION_EDIT, dat=file://sdcard/file.txt, cmp=some.component.name} ✓	{act=ACTION_DIAL, data=file://sdcard/file.txt, cmp=some.component.name} FUZZED

- Blank Action or Data

{act=ACTION_VIEW, dat=https://youtu.be/j5dMnAP242Z, cmp=some.component.name} ✓	{dat=https://youtu.be/j5dMnAP242Z, cmp=some.component.name} FUZZED

- Random Action or Data

{act=ACTION_EDIT, dat=content://contacts/people/1, cmp=com.android.contacts} ✓	{act=ACTION_EDIT, dat=q1w2e3Q!W@E#, cmp=com.android.contacts} FUZZED

- Random Extras

{act=ACTION_INSERT, dat=content://contacts/people/1, cmp=com.android.contacts (has extras)} ✓	{act=ACTION_INSERT, data=content://contacts/people/1, cmp=com.android.contacts (has random extras)} FUZZED

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Slide 9

SB2 Explain each type of FIC by giving the correct and the fuzzed versions.
Saurabh Bagchi, 6/24/2018

SB3 Which is random here? And what is "Data"?
Saurabh Bagchi, 6/24/2018

EBY6 Either the action or the data can be random, but not both at the same time.
Edgardo Barsallo Yi, 6/26/2018

EBY7 Data: An URI that represents the data item to be operated
Edgardo Barsallo Yi, 6/26/2018

Target Applications

- **Categories**: Health/Fitness and Not Health/Fitness
  - Based on the fact that health/fitness tracking apps are prominent in AW ecosystem (use of hardware and software sensors)
- **Classification**: Built-in and Third-party apps
  - Built-in apps are pre-installed on the wearable device, while third-party apps are installed by the user
- **Maturity Level:** Third-party apps with at least 1M downloads from the Google Play Store
- **Comparison between Android and AW Ecosystem**:
  - We conducted similar experiments on Android using QGJ-Main
  - We focused on Android built-in apps which are often used by third-party application for implementing common functionalities (**com.android**)

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Experimental Configuration

- QGJ-Master
  - Android 7.1.1 (released Dec 2016)
  - Android Wear 2.0 (released Feb 2017)
- QGJ-UI
  - Android Wear 2.0 (Emulator)
- Applications

OS		Classification	#	# Activities	# Services
AW	Health/Fitness	Built-in	2	81	34
AW	Health/Fitness	Third Party	11	80	59
AW	No Health/Fitness	Built-in	9	168	188
AW	No Health/Fitness	Third Party	24	185	117
AW	**Total**		**46**	**514**	**398**
A	**com.android**	**Built-in**	**63**	**595**	**218**

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Error Manifestations

- System Reboot
  - The OS reaches an unrecoverable state and the device reboots
- Crash
  - Application crashes due inability to handle malformed intents
- Hang or unresponsive
  - The application experiences temporary unresponsiveness or freezes permanently
- No effect
  - No effect or failure manifestation due to the malformed injection

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Distribution of Behaviors Among Fuzz Intent Campaigns

	Reboot		Crash		Hang		No Effect	
	Health	No Health	Health	No Health	Health	No Health	Health	No Health
Semi-valid	8%	0%	23%	30%	8%	0%	62%	70%
Blank Action or Data	0%	0%	31%	24%	0%	0%	69%	76%
Random Action or Data	0%	0%	31%	33%	8%	0%	62%	67%
Random Extras	0%	3%	15%	30%	8%	0%	77%	67%

- System Reboots occurred on both categories
- Injection has no effect at roughly the same rate (~70%) on both categories

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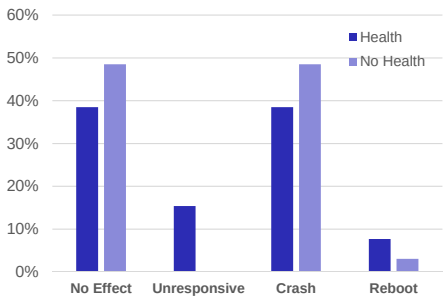
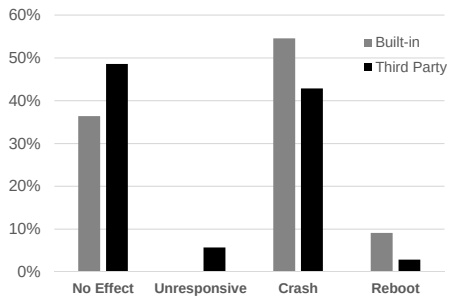
Slide 14

SB4 This is not clear. Please reword.
Saurabh Bagchi, 6/24/2018

EBY5 Reworded.
Edgardo Barsallo Yi, 6/25/2018

Reliability per Category





No significant difference between **Health/Fitness** apps and other apps

Built-in applications showed more failures compared to **Third Party** apps

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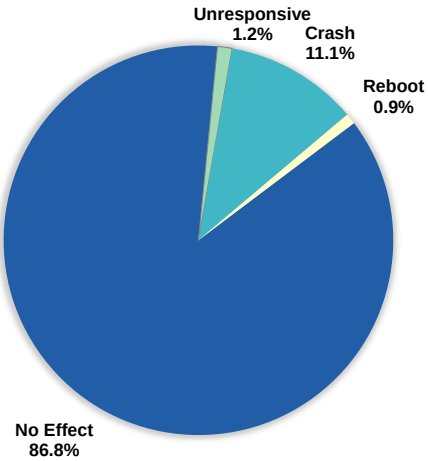
How Reliable is the Wearable Software Stack?



- Distribution of error manifestation among the application components
  - 13% of components reported failures
  - Crashes are more common than unresponsive manifestation (9X)
  - System reboots affected less than 1% of components

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Distribution of Crashes

75%

Exception	#Crashes	%
NullPointerException	54	30.9%
ClassNotFoundException	46	26.3%
IllegalArgumentException	31	17.7%
IllegalStateException	10	5.7%
RuntimeException	9	5.1%
ActivityNotFoundException	7	4.0%
UnsupportedOperationException	6	3.4%
Others	12	6.9%

Android

73%

Exception	#Crashes	%
NullPointerException	42	53.2%
IllegalStateException	10	12.7%
IllegalArgumentException	9	11.4%
ActivityNotFoundException	4	5.1%
Exception	4	5.1%
WindowManager$BadTokenException	3	3.8%
ClassNotFoundException	3	3.8%
Others	4	5.1%

Android Wear

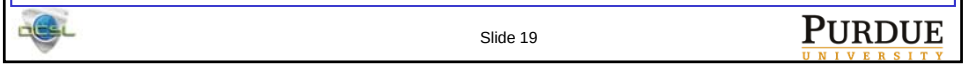
Resilience against UI injection

Experiment	#Injected Events	Exceptions Raised	Crashes
Semi-valid	41405	1496 (3.6%)	22 (0.05%)
Random	41405	615 (1.5%)	0 (0%)

- QGJ-Master focus on the communication between components (either starting an Activity or a Service)
  - After, an activity or service has been started, some user interaction (UI events) take places.
  - QGJ-UI emulates this interaction to test the robustness of apps
- No system crash during the UI injection
- Fewer number of exceptions and crashes than QGJ-Master
  - QGJ-UI only injects events to launcher activities
  - adb tools have a robust input validation

System Crashes from User-level Application

- No extra permissions at install time
- The manifestation depends on the transient state of the device
  - The reboots were not triggered by single intent, but due to error propagation across components and software aging through repeated fuzzing campaigns.
- 2 apps crashed Android Runtime
  - A health app (third party) raised a **SIGABRT** signal during the experiment, after experiencing some unresponsiveness.
  - A built-in app raised a **SIGSEVG** signal. The app crashed multiple times during the injection before triggering the reboot.



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Slide 19

SB5 Not clear. Please reword.
Saurabh Bagchi, 6/24/2018

EBY4 Reworded.
Edgardo Barsallo Yi, 6/25/2018

Conclusions and Insights

- **Distribution of exception** types differ between Android and Android Wear
  - Input validation (e.g. NullPointerException) is still the major cause of crashes
  - High incidence of crashes on AW are tied to the state of the application/device (e.g. IllegalStateException)
- **Software Aging**: Further research on software aging can help identify and mitigate transient system reboots that are state dependent
- **Input Validation**: Although Android's input validation has improved compared to earlier work [Maji, DSN'12] it is still a major cause for crashes.
  - Need more awareness and tool support

Slide 21

SB6 This seems like a vague hand-wavy insight - instead provide some evidence behind the top level bullet.
Saurabh Bagchi, 6/24/2018

EBY3 I added some notes too.
Edgardo Barsallo Yi, 6/25/2018

SB7 This has not been mentioned anywhere in the rest of the presentation. What is the context or evidence behind the claim?
Saurabh Bagchi, 6/24/2018

EBY2 I included some reference to software aging on slide 19: System Crashes from User-level Application.
Edgardo Barsallo Yi, 6/25/2018