

Notification Delays in Wearable Devices

Taniza Sultana

College of Engineering and Applied Science
University of Colorado Colorado Springs
tsultana@uccs.edu

Dr. Kristen Walcott

Department of Computer Science
University of Colorado Colorado Springs
kwalcott@uccs.edu

Abstract

Wearable devices such as smartwatches and fitness trackers can communicate with smartphones, laptops, and IoT devices, and they are growing in popularity. From these devices, the wearer or other connected devices can receive email or text notifications, health information, and much more.

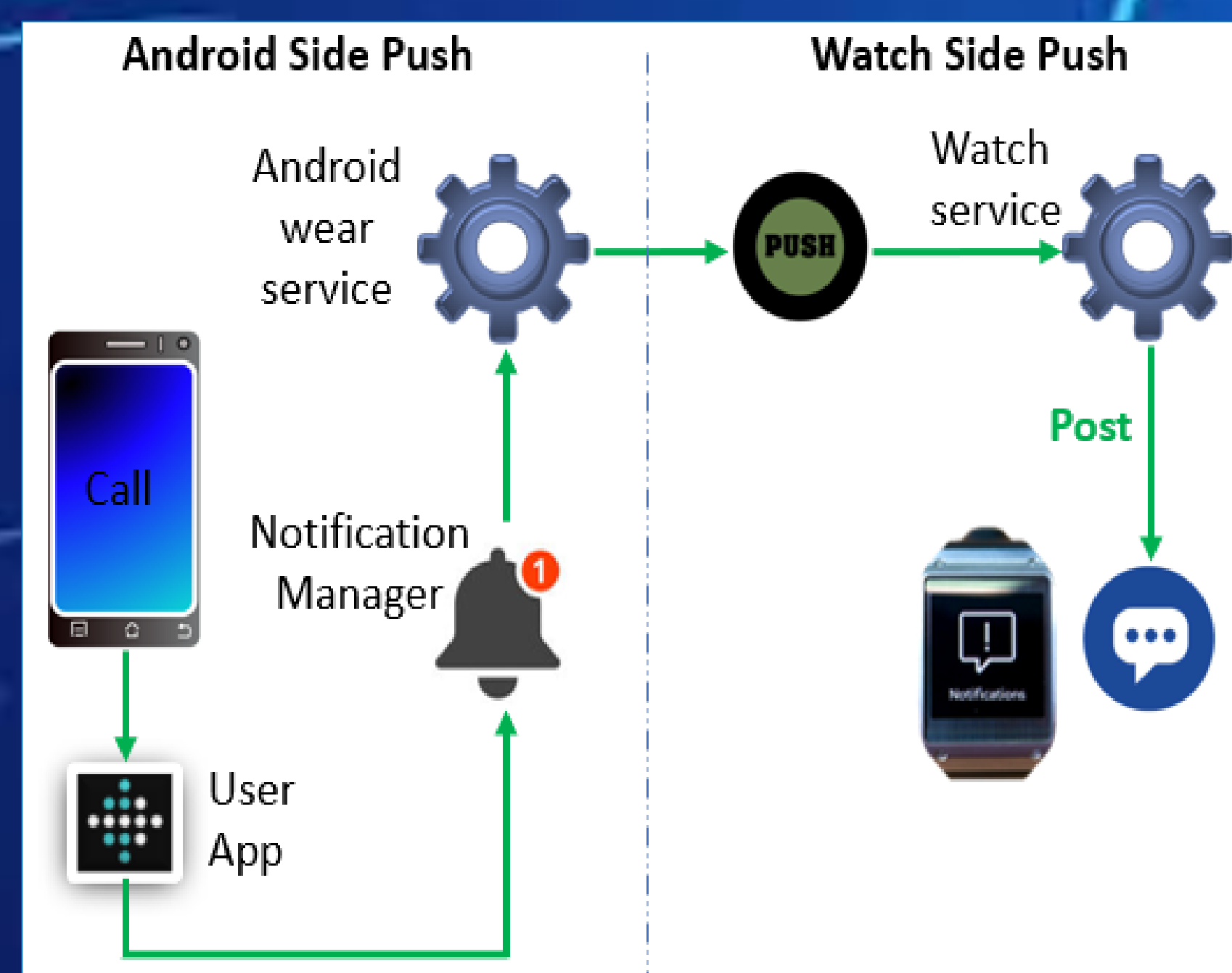
Main Challenge: The timing of receiving such notifications can be critical, and the delay to receive notifications varies between devices, leading to possible risks. What causes these delays?

Research:

- Examine call notification delays in smartwatches and cellphones to determine causes of delay of notification.
- Compare Android phones and their connected smartwatches to analyze differences between devices, network setup, memory usage, and other factors.

Key Contributions:

- Evaluation of notification push delays in varied Android phones.
- Analysis of separating factors in network architectures, system and software designs between the devices with the delay behavior in call notifications pushes.
- Identification of influencing vectors that affect notification timings.



Communication is slow between devices - Why?

Android wear service determines “push” or “not to push” based on phone’s settings.

Connected devices do not see information until a POST.

Reception of the POST depends on the connected device’s state and settings.



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Colorado Springs

Discovery and Evaluation

Experiment Setup

Tests 32 sets of devices in 22 different combinations at four different physical proximities (0 feet, 5 feet, 10 feet, and 20 feet) and the following four settings:

Config 1: Test phones connected to the same Wi-fi.

Config 2: Test phones while connected to the same Wi-fi with the watch-side applications notification function in the phone set to “call notifications” and “text notifications.”

Config 3: All phones disconnected from Wi-fi and use their own phone carrier service with the watch-side applications notification function in the phone set to “call notifications.”

Config 4: Remove all smartwatches from their connected phone then re-connect them to sync back to their app.

Experiment Goals

- Evaluate the correlation between smartwatch call notification delay and physical proximity.
- Analyze the delay variance between the types of smartwatch and the types of connected smartphone.
- Analyze the delay variance between smartphone Wi-fi connection and phone carrier service.
- Examine differences in hardware design, software, and network architecture between least-delay and most-delay devices in call notifications.
- Identify vectors that affect notification timings.

Overall Results

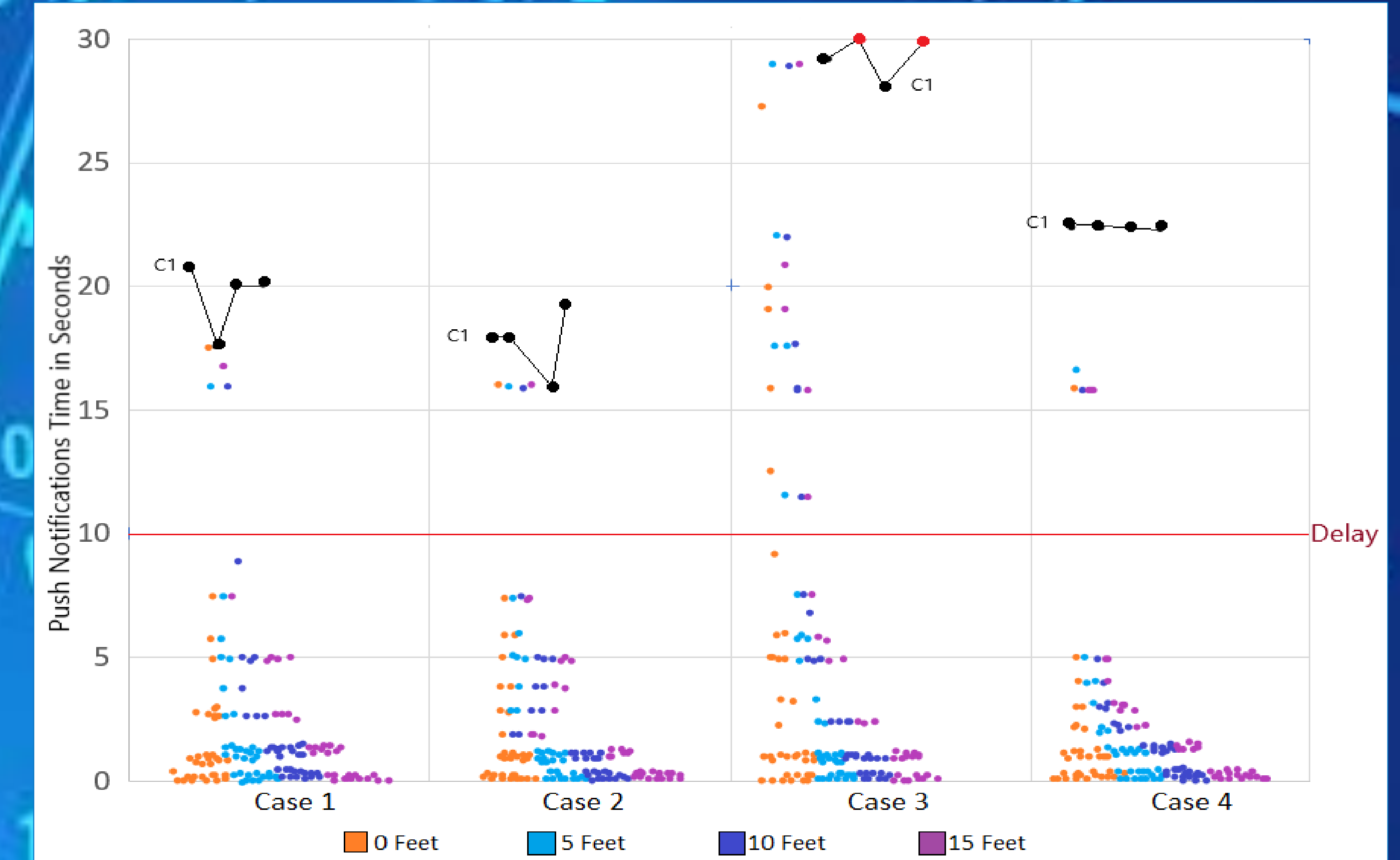
Notifications are not all received immediately. Many factors impact the timing of notification.

Smartphone/SmartWatch Combos

Galaxy S6 - Fitbit Alta	Galaxy S9 - Fitbit Versa
Galaxy S6 - Fitbit Charge 2	Galaxy S9 - Fitbit Char 3
Galaxy S6 - Fitbit Charge 3	Galaxy S9+ - Galaxy Watch
Galaxy S6 - Gear S3	Galaxy S9+ - Fitbit Versa
Galaxy S6 - Galaxy Watch	Galaxy S9+ - Fitbit Char 3
Galaxy S7 - Fitbit Charge 3	Galaxy S9e - Fitbit Versa
Galaxy S7 - Gear S3	Galaxy S9e - Fitbit Char 3
Galaxy S7 - Galaxy Watch	Galaxy S10 - Iconic
Galaxy S8 - Fitbit Versa	Galaxy S10 - Fitbit Versa
Galaxy S8+ - Gear Fit2 Pro	Galaxy S10+ - Fitbit Versa
Galaxy Note8 - Fitbit Char 3	Galaxy S10e - Versa Lite

Avg Push Notification by Phone (s)

Device	Config 1	Config 2	Config 3	Config 4
Galaxy S6	6.2	6.05	15	5.5
Galaxy S7	2.56	3	8.69	2.19
Galaxy S8	2.25	3	2	2.25
Galaxy S9	1	0	1	0
Galaxy S10	0	0	0	0



Influencing Vectors

Factors impacting notification delays were observed across two devices. The key factors impacting delays were:

- Stored Data Volume vs. Free Memory
- Version of Phone
- Do Not Disturb Setting
- Phone Carrier Service
- Application Updates

Property	Samsung Galaxy S7	Samsung Galaxy S7
Wi-fi Network	✓Same	✓Same
Bluetooth Settings	✓Same	✓Same
Carrier Service	Sprint	Sprint
Test Location	✓Same	✓Same
Watch App Settings	✓Same	✓Same
Device Memory	32GB	32GB
Stored Data Volume	31.2GB	30GB
Free Memory	856MB	2GB
Android Service Setting	Do Not Disturb	None
Application Updates	None	None

Conclusion

Notification delays across devices can cause risk, especially with regard to health devices, security warnings, and other alerts. We observe that these delays do exist and identified some factors that impact delays across devices.

Future Work:

In upcoming work, we intend to automate performance and state analysis for large numbers of smartphones and smartwatches. In this, we will consider

- Calls, Text, social media, and medical alert notifications.
- A larger range of domain properties for more precise vector analysis.