SUKRITI CHADHA: Hi, we're from the Yahoo Finance Android team. I'm Sukriti Chadha. I'm a product manager on the Android side and also on some horizontal projects. And I have Yatin Kaushal, who is the lead engineer on this project. We also have Kisiah Timmons, who helped us with this project from the accessibility team at Verizon Media.

So a little bit of context on the Audio Charts Project. It started off with an informal conversation between me and a mobile architect who worked horizontally across the different mobile apps at Yahoo. And the conversation was about accessibility on mobile in general, but more specifically on the finance use case, where, as you see on the right, there is hundreds of data points presented at any given time. In this case, it's a three-month chart for Verizon. And for a visually limited user or a visually impaired user, it's incredibly hard to get that kind of information that a sighted user has access to just by the fact of representing so many data points in the form of a graph.

The status quo or standard practice for showing this kind of information to a talk back or a screen reader user is reading it in the form of a table where, when we did our user studies, the patterns or the overall movement of the data over time was lost after just five or eight data points for a lot of users. And to consider hundreds of data points being relayed that way was accessible in the sense that they still had access to it. But it's not truly usable, especially in the context of financial markets where time is of the essence. And that's what led to the inception of this project, which is to use music in terms of pitch and some other music qualities and haptics to convey the same information in a much more time efficient way.

We have now also open-sourced this project, thanks to Yatin's hard work, which is now available to the overall Android community. And any app that has a line graph implementation can very easily put our solution over and make their apps not just accessible, but truly usable for all of their users. The links to the GitHub page and the blog post that talks a little bit more about the context and the implementation is linked here. I'd also play how the finance accessible charts work just to give some context as to what the implementation and application looks like when it comes to life.

AUTOMATED VOICE: Easy three months chart. Double tap to explore. Double tap to activate. Easy three months chart trending up. Current price, $59.75. Previous close, $57.63. High, $59.96. Low, $59.59. Swipe or drag two fingers across the chart to explore. Double tap to activate.

[BEEPING OF VARYING PITCHES]

The 2nd of September 2019, $59.06, enlist 15 items. August 26, 2019, $58.16. August 19, 2019, $55.92. The 12th of August, 2019, $56.65. Easy three months chart.

[BEEPING OF VARYING PITCHES]

Settings, Navigate Up button. Double tap to ac-- settings, double tap to activate. Controls, links, headings, 12:00 AM 57.7-- 12:00 AM, 55.59 heading. 12:00 AM, 55.78 heading. 12:00 AM, 59.96 heading. Navigate Up--

SUKRITI CHADHA: So that just gives a summary of how the solution overall works. There are some nuances in the experience overall that I'll touch on in the next slide, which covers the product and design considerations that went into making this interface come to life.

In terms of how the solution is architected, it's converting the digital information, which is the numbers on the y-axis, in this case, and scaling that to human audible range of frequencies and a pleasant range of frequencies that we can hear. And after we do that, the pitch then maps on to the numbers on the y-axis of the chart. And as the user scrolls back and forth between one edge of the screen to the other, the tones are played. And if there is a point of interest to the user, they can decide to stop there and scroll back and forth for individual data points. And that seamless transition between the frequency and the actual data point being read back to them is what makes this solution novel and exciting for the users.

The reason we chose to do a full screen experience is that it's easier for users that don't have complete 100% vision is that recognizing the two ends of the device is much easier than trying to navigate a complex thing like a chart within the context of a larger screen where there is a lot more elements competing for focus.

The audio feedback is the data point which, in this case, is, for example, August 20, 2019 stock price, x, y, and z. And that's the format that is the default. In the Settings page, the users can pick other formats which are less or more verbose, depending on what they prefer. Because the most important lesson we learned from doing user studies and then launching this at scale was that every user has their own nuanced expectations of what the experience should look like and what they need from a chart, especially in the finance context. And we've

made it as customizable as possible.

There is also a haptics element to it, which is not apparent in the PowerPoint. But when you stop at a point of interest or a high, or a low, or start date, a start price, or an end price in the stock case, for example, there is also a haptic feedback that you get while you're scrolling back and forth to inform the user that it's a point of interest and something they might want to explore further.

Here's a drawing of user studies that we did with eight users. There's a few graphs here of the users that we're following, data patterns that are shown in the graph that's pink on the right-- the left-hand-- bottom-left corner, I'm sorry, and what a set of users drew after listening to the pitch. And as you can see, a lot of people were able to get the overall pattern from the chart. And that's what we were hoping for. It was not to convey the actual numbers.

But the overall problem that we were trying to tackle was that people should be able to get the overall pattern or the trend of the data that they were looking at from this music and haptics combination. And many of the users that we tested with were able to draw this upward-trending graph with a little bit of a low with one exception. So it seemed very promising from the very beginning. And as we customize the solution further, the results became a lot better.

Now to the engineering part, where Yatin can talk about what went into actually building this.

YATIN KAUSHAL: So from the engineering perspective, we started with rendering the chart itself. We used Android's native library, Canvas, to render the chart as well as draw any axes and labels on it.

Once the chart was rendered, we then placed a Recycler view above the whole chart, which would then render the data points. These data points are represented as invisible columns. And when talkback is enabled, the user can focus on one of these invisible columns and hear TalkBack read out loud the time and price of that data point. In the Settings page, you can change the format in which TalkBack reads out loud that data point. With TalkBack enabled, the user can also swipe from one point to the next.

The user can also press and hold two fingers, which will then engage the tone generator. In this mode, you can scrub both your fingers across the chart and hear a tone whose pitch will correspond with its placement on the trend line. The higher the point, the higher the pitch of the tone. The pitch range can also be modified in the settings.

Here's the high level architecture diagram, showing how an app could expect to use the open

source Songbird library. The app would use the Songbird chart view on whatever page it would like to show the chart. It would then provide a view model which will have information like the data points and any labels. And it can also ask the chart view to play the summary audio. This will loop through all of the data points and play each of their tones, giving the user a sense of the overall trend of this chart.

Once the app is done using this chart view and wants to clear up its resources, it can call its disposed method. And internally, the chart view uses an audio helper which will be notified whenever a scrubbing event or a release event has happened, and then play the tone accordingly. Over half of our talkback-enabled user base is interacting with audio charts. And some of the next steps that we would like to take are to improve the tone sound, allow for more customizability of that chart view itself, as well as support any feature that come in on our Github repository page.

SUKRITI CHADHA: In terms of some of the other applications of audio charts, or just the audio translation of digital information, we see applications across voice assistance, like Alexa or Google Home. Some applications are also on desktop, where it's not as interactive, but it's as important to make those interfaces, and charts, and digital information that's primarily visual accessible through haptics and music.

The third and more important one would be educational where, for example, Kisiah talks about her experience with getting an MBA and using books that had graphs and charts all over the place and not an easy way to access them. So we could easily envision a QR code, for example, and that deep linking into an Android app that translates this information to users who would like to then quickly see the trend of a given chart. And we'd like the mobile community to take this on with the initial sort of prototype or implementation of the project that we have put as an open source project.

One of the feedbacks that we got from our users on the app store is mentioned above, which was really heartening to see. And this is a user who used to be a forex trader and never thought they had a chance at doing that again. And because of this solution, they now believe they can. And that's what makes putting all this effort into making something like this possible and being at a company that supports and appreciates the work that we do towards accessibility.

So that's been great. We'd love to hear questions, comments that you all have. And thank you

so much.

YATIN KAUSHAL: Thank you.