There are a lot of benchmarks to measure the speed of a smartphone. But most of them consider only singular aspects of performance like CPU speed, memory transfers or Graphic speed and completely neglect human interaction with the device under test. connect uses a more holistic approach to measure the reaction time of smartphones under a variety of conditions.

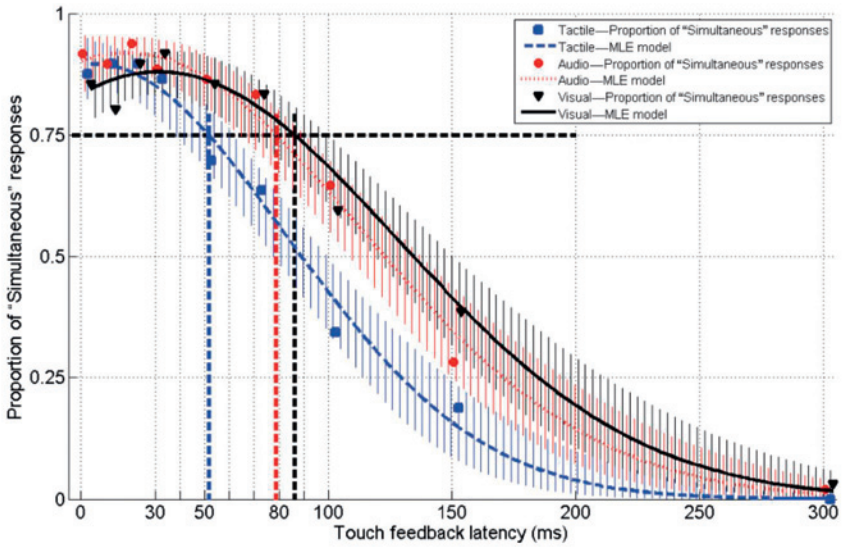
A NEW METHOD TO MEASURE SMARTPHONE SYSTEM PERFORMANCE

Over the last years the performance of smartphones has improved a lot. Higher processor clock rates, more cores and more main memory to keep all running apps instantly available are some of the main ingredients to enable this progress. The results can be seen with modern benchmarking apps like Geekbench, Antutu, 3Dmark and the like. These apps are well suited to document the progress. But despite their usefulness they have a number of drawbacks:

- they are optimized for a certain operation system generation and do not take processing advantages of later versions into account.
- they often change their measuring scope and performance rating metric. Therefore the benchmark results are not comparable on a long term basis.
- many of them are only suitable for measuring isolated aspects of performance, like integer processing power, memory access read/write speed, frame rate or the like.
- they do not take user interactions into account, which can be responsible for response delays by themselves
- they most often only measure the time which is necessary to conduct certain tasks und not the user experience impaired by delays in response.

To get a more holistic view on the influence of smartphone speed on user experience it is first necessary to understand how fast a smartphone must respond to be perceived as free of delays.

This topic was researched 2014 by Topi Kaaresoja, a scientist specialized in Human-machine interfaces associated with Nokia. He came to the conclusion that the delay between touchscreen input and display reaction must be within a time frame of 86 milliseconds to be perceived as concurrent. As the reaction time of modern smartphones usually lies well above this threshold, any decrease will be perceived as an advantage. And with the use of a few dedicated components, reaction time should be easily measureable on common applications.



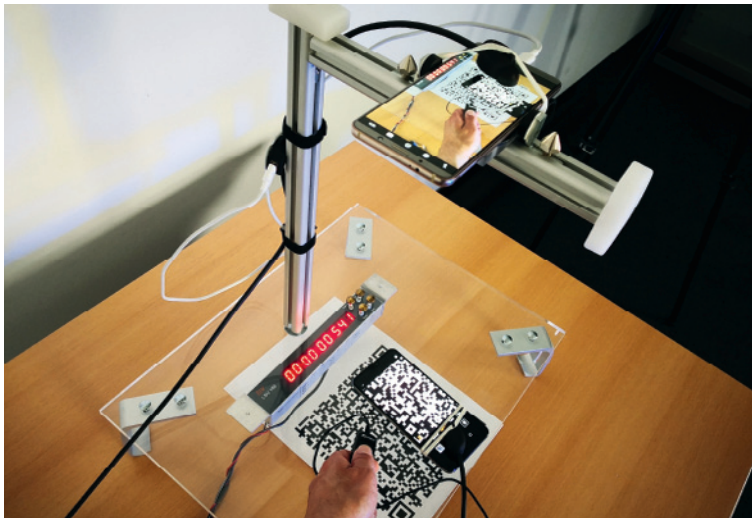
It should not take more than 86 milliseconds if a touchscreen tap and the event triggered by it are to be experienced simultaneously.

A new approach to measure reaction time

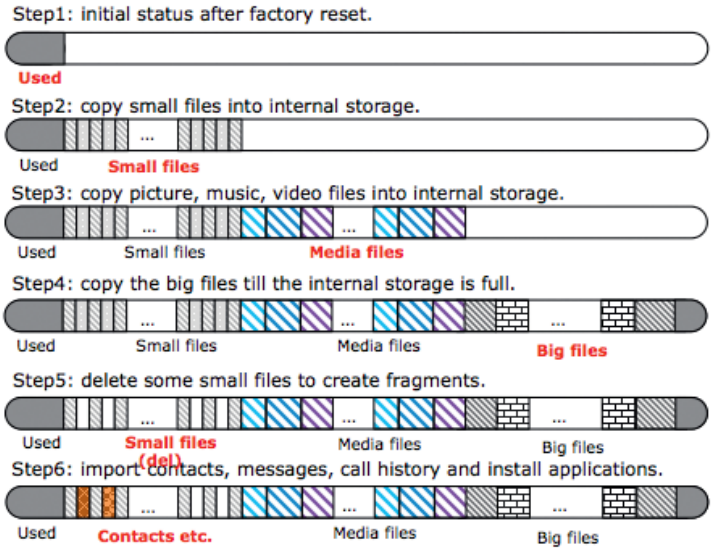
The basis of the measuring setup described herein are two virtual fingers "iQ-Trigger-T" by Image Engineering, an electronic stopwatch, a couple of electronic timers and a smartphone used as a high speed video camera that is able to record 120 frames per second.

One of the virtual fingers is placed on the smartphone under test on the app, button or file, which should be agitated to measure the response time.

Each single measurement is started by the push of an external button. This also starts the high speed video camera with the help of the first virtual finger and a timer. A fraction of a second



The assembly to measure smartphone speed consists of a transparent plattform for the smartphone under test (SUT) and an electronic stopwatch. A smartphone used as a high speed video camera is placed above the SUT and the stopwatch.



After a reset to the factory condition the smartphone data memory will be filled with different file types. The filling process is designed to ensure a high level of fragmentation for the stored files.

later, this timer starts the second virtual finger on the smartphone under test and simultaneously the electronic stopwatch as well as another timer. The virtual finger will open an app or a file or start an action like taking a photo. After a time set by the second timer which has to be long enough to conduct the ongoing task, the high speed camera will be stopped again by the first virtual finger.

With the recorded video it is easy to measure the time it takes to conduct any task by simply reading the stopwatch when the task is finished. The resolution of this measurement is 1/120 second or 8.3 ms, about a tenth of the threshold found by Kaaresoja.

Although this method is more laborious than simply running a benchmark, it has many advantages. It is not only independent of the operating system version, but also of the type of operating system as a whole. As long as the apps under investigation are present on a smartphone, the method can be used. It is an end-to-end investigation from user input to completed reaction which takes the human perception of speed differences into account.

Aging – an important aspect of smartphone performance

And there is another aspect which is a clear advantage of this app-independent smartphone speed test: As many users have recognized, the speed of a smartphone can change considerably from the point in time when it is new to when the device has been used for a longer period of time. This is especially true for the so-called power users. We call this aspect "aging" – the smartphone is slowed down by a full data memory, lots of open apps on hold in the main memory plus lots of apps working in the background.

Cooperation with Huawei

As Huawei was working on the same topic at the same time, we decided to join forces on a preconditioning tool, which could be used to bring a new smartphone into a state which resembles a phone, which has been used for a very long time. Still, this is done in a repeatable manner.

Part of the aging process is to fill the flash memory with a bunch of different file types, then delete certain files to create

HIGH SPEED CAMERA MEASUREMENT

The analysis of the recorded video of an action allows the individual steps and the total time to be exactly timed. The picture shows the opening of the picture gallery with a sample photo. At the end of the action the total time is displayed on the stopwatch. Several repetitions guarantee high accuracy.

fragmented areas. These are then filled with contacts, messages, call history and installed applications.

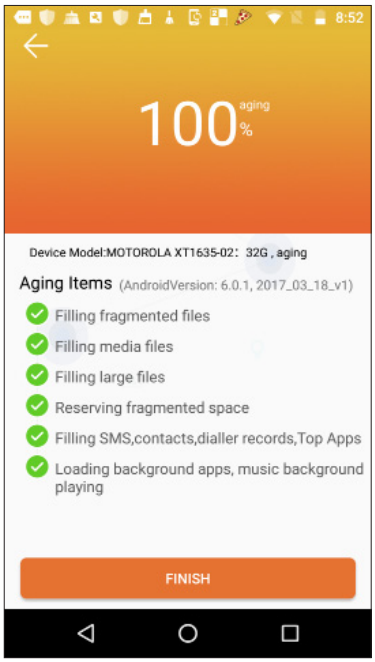
Another part of the aging process is starting installed applications to create the usual background traffic associated with a smartphone in use by a so-called power user. After these steps have been taken, the reaction time measurements can be made the same way as on the brand new smartphone.

Measured actions

In a first trial run, twelve different scenarios where checked. But for some of the measurements the repetitive accuracy was rather low. One reason for this was that a complex action was not always conducted in the same manner or order by the operating systems.

Nonetheless, five scenarios were demanding enough to encourage a measurement and delivered very stable results from one measurement to the next. These scenarios are: Opening the messaging client, opening the camera, opening the Chrome browser with Google as homepage, opening Google photos and opening a picture within Google photos. The tasks took between 486 milliseconds (opening pictures) and 977 milliseconds (opening camera) on average and 386 milliseconds as a minimum. So a speed increase would for sure result in a better user experience.

The virtual finger ensures a very accurate starting point of every action to be measured.



A special app just takes hours to put the smartphone into a state that would normally be reached only after months of intensive use.

First test

For a first trial, five devices have been put on the bench. A Galaxy S9+ and a Note 9 from Samsung, a Google Pixel XL2 as well as a Mate 20 and a Mate 20 Pro from Huawei took part in the first investigation.

All of these devices are high end models of their manufactures and therefore it is no wonder that their response times are all in the same order of magnitude. Apart from this, the Huawei Mate 20 and Mate 20 Pro showed a slight advantage in overall performance and proved to be more robust against aging in these tests. Whether this is a result of the additional work that Huawei has put into the operating system in order to work against the effects of aging remains to be seen.

BERND THEISS, HEAD OF TESTLAB

RESULTS

MANUFACTURER	SAMSUNG		GOOGLE		HUAWEI		HUAWEI		SAMSUNG	
Model	**S9+ (64GB)**		**Pixel XL2 (64GB)**		**Mate 20 (128GB)**		**Mate 20 Pro (128GB)**		**Note 9 (128GB)**	
Measuring Condition										
Zustand	initial	aged	initial	aged	initial	aged	initial	aged	initial	aged
Opening Messaging (CA)	560	681	1059	1415	686	951	660	721	607	1080
Opening Camera (fs)	862	987	923	951	1124	1027	992	986	854	1063
Opening Chrome browser with Google as Homepage (CA)	1018	1023	947	945	542	541	463	504	967	1157
Opening Google Photos (FS)	610	752	644	682	521	610	504	522	608	716
Opening Picture the first time from Google Photo App	507	612	494	571	482	449	386	393	489	478
Average Response Time	**711**	**811**	**813**	**913**	**671**	**716**	**601**	**625**	**705**	**899**
Average Time	**761**		**863**		**693**		**613**		**802**	
Aging Rate										
Opening Messaging (CA)	0,22		0,34		0,39		0,09		0,78	
Opening Camera(fs)	0,15		0,03		-0,09		-0,01		0,24	
Opening Chrome browser	0,00		0,00		0,00		0,09		0,20	
Opening Google Photos(FS)	0,23		0,06		0,17		0,04		0,18	
Opening Picture	0,21		0,16		-0,07		0,02		-0,02	
Average Aging Rate	**0,16**		**0,12**		**0,08**		**0,05**		**0,28**	