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Possibility of using Smartphones in Distributed Computing Networks

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***Abstract*—In this article the possible use of smartphones, as potential resources in a distributed computing system has been examined. First, the performance indexes of smartphones, desktop and notebook computers were compared, considering the six year period of the iPhone product line. In the second part some volunteer computing projects were summarized in a glance, to have a better picture of the necessary performance and donation system. Finally some motivating ideas have been proposed, to gather more donors for a smartphone based distributed computing network.**

***Keywords*— Distributed Computing, Performance index, Geekbench, Smartphone, Smartphone performance**

I. Introduction

In recent years many researches examine the feasibility of using smartphones (or similar mobile devices) in sensor, grid, or cloud networks. Between 2010 and 2013, the performance of top smartphones is highly increased. In 2014, the majority of the most powerful models are still using 32 bit architecture, but these devices are equipped with quad, or at least dual-core CPU-s, dedicated quad/dual core GPU-s, and with 1-2 GB RAM. In February 2014, Qualcomm Technologies announced world's first commercial 64-bit octa-core chipset, the Snapdragon 615. [1] The total performance of these high-end devices, released in the mentioned year, is much the same as the performance of an iMac or MacBook Pro sold in 2009. In light of the huge amount of mobile phones, especially modern smartphones all over the world, the total computational power of these devices seems to be immense. If we consider the fact, that smartphones practically have nothing to do in the biggest part of the day which would need the maximum or high performance, it sounds logical to find a way to harness this remaining capacity either in part or as a whole. Of course if we want our mobile phone to remain mobile, because the limited battery capacity, we can not use classic CPU scavenging. But during night-time mobility is not usually used. In this period it is not problematic to operate mobiles – using the charger – from line-power, and we have the chance to embrace this opportunity with full power operation as the part of a smartphone based distributed computing system.

Collecting instruction cycles from smartphone CPUs can only be effective with wide participation of mobile phone users, which is the key to reach notable computing power. But can we reach any considerable result in the shadow of desktop based distributed networks, grids or supercomputers?

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Can the large number of smartphones counteract the limited resources in comparison with desktop computers? Is it worth the efforts to elaborate new and more efficient techniques to connect smartphones to a distributed computing network? We are looking for the answers of these and similar questions in this article.

II. Comparing Method

To see the real power of the newest smartphones, we have to compare their performance to desktop or notebook computers. It is not a simple task, because comparing the CPU performance only (which is also difficult), would not reflect on the real performance of the whole system. Actually, there are many benchmarks available to compare the full system performance, instead of CPU execution speed only, but most of them are limited to desktop or mobile systems. In some other cases, when both versions are available, the results are not comparable to each other.

For these reasons in this comparison Geekbench, a cross platform processor benchmark has been used. Geekbench measures not only the processor's integer and floating point performance, but the memory, and memory bandwidth performance as well, and the final score is calculated from the weighted average of these values. "Geekbench 3 scores are calibrated against a baseline score of 2500 (which is the score of an Intel Core i5-2520M @ 2.50 GHz). Higher scores are better, with double the score indicating double the performance." [2] Unfortunately Geekbench is not providing results about graphic performance, though GPU based solutions are more effective in some special fields. Important to know, Geekbench tells nothing about measurement circumstances (i.e. environmental temperature), and also depends on the software environment (software and kernel version). For these reasons any repeated test usually results in slightly different values, depending on the actual state of the tested device. To compare desktop and smartphone performance, or see the characteristics of the increased performance, Geekbench's Results Browser based average values (in case of Apple and Android devices) and Geekbench Search average values (for all other systems) have been used.

III. Smartphone Performance

First, to see the rising tendency of smartphone's performance, the Apple iPhone series have been examined. The limited product line and the relatively early appearance of the iPhone family make it ideal for an initial inquiry. It is also important that iPhones and the iOS are really popular nowadays. Average Geekbench 3 results from different generation of iPhones are represented in Fig. 1.

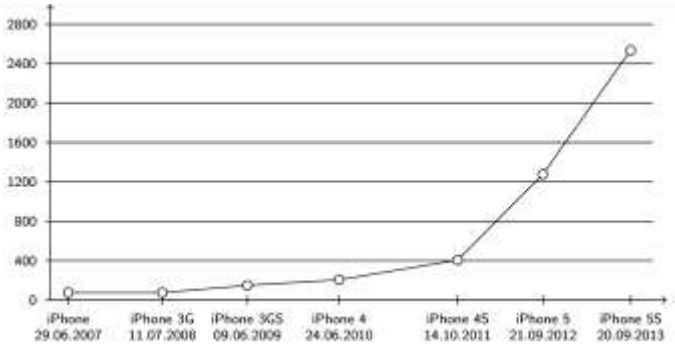

Figure 1. Benchmark values of the iPhone product line [3]

Fig. 1 clearly shows that the real break away started with the iPhone 5, which is much more powerful than the former versions. The next generation, iPhone 5S added a significant extra performance again, but it is still to be examined that this performance is equivalent to which desktop or notebook systems. Based on the multi-core benchmark results, the iPhone 5S has quite the same performance index than a MacBook Pro (Late 2008) equipped with Intel Core 2 Duo T9400 2530 MHz (2 cores) CPU and DDR3 memory, and it has higher index than some low end category notebooks in 2014!

To have a better picture on smartphone's performance, the most popular and powerful models from different vendors are examined as well. Table I. contains the details of the Top 5 Android smartphones, based on Geekbench 3 Android multicore benchmark results on 09.05.2014. For comparison, the iPhone 5S performed the same test with 2535 points.

TABLE I. TOP ANDROID SMARTPHONES [2]

Smartphone	*Cores*	*Frequency*	*Benchmark*
Samsung Galaxy S5	4	2457 MHz	2873
Sony Xperia Z1	4	2150 MHz	2666
LG Nexus 5	4	2265 MHz	2552
Samsung Galaxy S4	4	2265 MHz	2304
LG G2	4	2265 MHz	2252

To see what these top smartphone performances worth in 2014, some desktop and notebook benchmark indexes were also collected. Table II and Table III contains mainly office class desktop and notebook computers currently available, similarly to smartphone models in Table I. All the scores in Table I and Table II are 32-bit, multi-core values.

The listed desktop and notebook computers work in 64-bit environment as well, but in case of the most systems the used database does not contain enough 64 bit test results to have adequate values. Based on the Macintosh systems, the 64-bit scores are 11% higher in average than the 32-bit results. As you can see, the top smartphone scores are similar to the results of low-end category notebook systems released in the same years.

TABLE II. SAMPLE DESKTOP PERFORMANCES [4]

Desktop / Workstation	*CPU*	*Benchmark*
HP EliteDesk 800 G1	Intel Core i7-4770	13294
iMac (14,2)	Intel Core i7-4771	13087
Dell Precision T1700	Intel Xeon E3-1240 v3	13073
Dell OptiPlex 7010	Intel Core i5-3570	10387
HP Compaq Pro 6300	Intel Core i5-3470	9332
Dell OptiPlex 3020	Intel Core i3-4130	6273
HP Pro 3500 Series	Intel Core i3-3220	5305

TABLE III. SAMPLE NOTEBOOK PERFORMANCES [4]

Notebook	*CPU*	*Benchmark*
MacBook Pro (11,3)	Intel Core i7-4850HQ	11805
Dell Latitude E6430	Intel Core i7-3740QM	11617
MacBook Air (6,2)	Intel Core i7-4650U	5490
HP ProBook 640 G1	Intel Core i5-4200M	5428
Dell Vostro 3560	Intel Core i5-3210M	5185
HP EliteBook 840 G1	Intel Core i5-4200U	4257
Dell Vostro 2521	Intel Core i3-2375M	2423

The tables above contain only test values of some popular, but randomly selected computers. Because of the wide range of smartphones, notebooks, and desktops, it is impossible to gain all necessary data to a comprehensive survey. We can only estimate the performance ratio between smartphones and desktop (notebook) systems. Based on non representative values of Table I, II, and III, we can compare the highest performance smartphones to some low-end, average and business category computer systems, but these lists only enable us to have a closer look at the performance ratios, see magnitudes, but inconsistent to come any conclusion at this time.

It is more interesting to compare the performance indexes of different types of devices (smartphone, desktop, and notebook) from the same vendor and with the closest possible release dates. Apple products provide a sound basis to this examination, because Apple is maybe the only company which is successful in all three fields. The limited product line also helps the comparison. To collect iPhone benchmark indexes is quite simple, because only 8 different models appeared in the market yet. Because iPhone 5c does not belong to the premium product line, as all other iPhones are, we will take only seven iPhones into consideration in this article. If we are talking about Apple notebooks or desktops, our task is not as simple, because of the large number of possible configurations of the same systems. For this reason only seven iMac, Mac Mini, MacBook Air, MacBook Pro and seven Mac Pro models, released between 2007 and 2014, were selected to this comparison. Each iPhone was compared to the closest released Macintosh system for homogeneous result, which sometimes means that the same computer was compared to different iPhones. In case of MacBook Air, the

models with 13 inch display were selected, and models with 15 inch display were used form the MacBook Pro family. In case of iMac systems, always the versions with larger displays were chosen. When the selected model (in any family) was available with more than one default processor configuration, always the one with faster CPU was picked for this evaluation. Fig. 2 represents the Geekbench 3 based performance ratio compared iMac, Mac Mini, MacBook Air, MacBook Pro systems to iPhones, between 2007 and 2013.

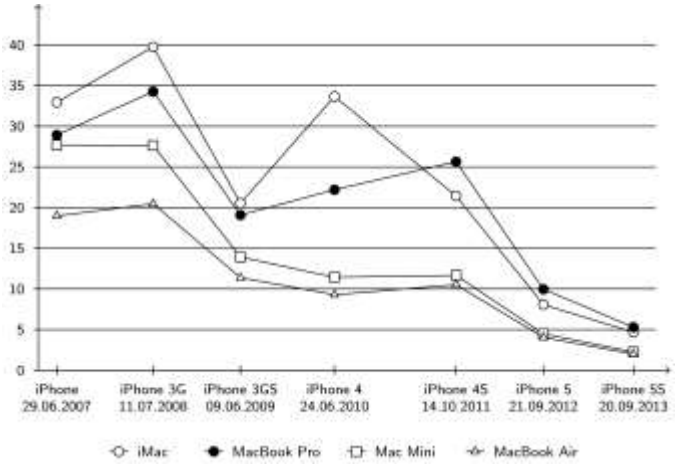

Figure 2. Benchmark performance index ratios

In 2007, when the first iPhone appeared in the market, the performance indexes of the compared systems were 19–33 times higher than the test result of Apple's first mobile phone. The end values belong to MacBook Air (Early 2008) with 18.98 times higher result, and to iMac (Mid 2007) which performs 32.95 times faster. Now, take a look to the latest models. With the appearance of the iPhone 5S (and all the other Apple computers in 2013), the benchmark indexes are only 2–5 times faster, considering the latest iPhone and the selected systems from the examined Macintosh families. Based on the benchmark results, the MacBook Air (Mid 2013) performs less than 2 times (1.98) faster than the iPhone 5S, and the biggest difference is only 5.29, compared to the late 2013 version of MacBook Pro. It is not included in the chart, but still notable that the benchmark index ratio between Mac Pro and iPhone families decreased from 150.35 to 8.17 between the debut of the first iPhone in 2007 and the appearance of the latest version in 2013!

Based on the remarkable reduction in performance index ratios (Fig. 2) it can be laid down as a fact that the difference in computing power between smartphones and desktop (or notebook) systems significantly decreased last years, and the tendency predicts further progress as well. For this reason modern smartphones could be real alternative clients, to increase the computing power of any volunteer computing projects.

IV. Volunteer Computing Projects

In volunteer computing participants offer (donate) their computing resources to a distributed computing system, to support chosen project(s). Traditionally, desktop and server computer resources were donated to add computing capacity to a distributed system, but the increased performance and the large amount of modern smartphones make these devices also considerable nowadays.

A. *Folding@Home*

The Folding@Home project was founded by Pande lab Stanford University, and supported by National Institutes of Health (NIH) and National Science Foundation (NSF) as well as many industrial partners. Folding@Home concentrates all donated resources to one goal, to understand protein misfolding better. Folding@Home uses not only classic CPU power, but can harness the GPU resources as well. On 17.05.2014 Folding@Home had 162,831 active CPUs and 71,660 active GPUs. The CPUs produced 681 native TFLOP, which performance is in the same range with the top BOINC projects. But the GPUs gave an extra 20,528 native TFLOP which is altogether estimated to 43,994 x86 TFLOP based on the data of Folding@Home statistic page. [5] With this total performance Folding@Home is one of the fastest computing systems in the World.

In connection to use new types of clients in voluntary supported distributed computing systems, Folding@Home and Sony had a novel initiation. Between March 2007 and 6 November 2012 more than 15 million PlayStation 3 users have participated in the Folding@Home project with more than 100 million donated computation hours. [6]

B. *BOINC*

The Berkeley Open Infrastructure for Network Computing (BOINC) is a multi platform, open source middleware system for volunteer and grid computing, founded and supported by the National Science Foundation (NSF). BOINC is the common platform for projects from many fields of science, like astronomy, physics, chemistry, biology, mathematics, etc. Table IV shows the number of active host and average floating point operations per second in TFLOPS of the five most popular projects in production state, based on BOINC stats/Project popularity values on 18.05.2015.

TABLE IV. THE FIVE MOST POPULAR BOINC PROJECTS

Project name	*Start*	*Active hosts*	*TFLOPS*
SETI@Home	21.07.2004[1]	187,292	695.505
World Community Grid[2]	01.11.2005	312,835	663.225
Rosetta@Home	22.09.2005	63,525	82.448
Einstein@Home	08.11.2004	356,214	552.542
Climate Prediction	11.08.2004	N/A	N/A

1) BOINC on Android

The Android version of the traditional BOINC client creates the possibility for any Android based smartphone or

[1] The first, non BOINC version of SETI@Home is started in 1999
[2] Runs multiple sub-projects

tablet owner to offer resources to a BOINC project. Currently 12 projects are supported, among others SETI@Home or Einstein@Home. Running a BOINC project on an Android device is not popular yet, but if we consider the shrinking performance ratio between smartphones and desktop/notebook computers, the active host number of the most popular BOINC projects (Table IV), and the huge amount (758,719,900 units were sold worldwide only in 2013 [7]) of Android based devices, it is clearly visible that modern smartphones represent remarkable, but mostly unused computing power.

V. User Motivation

The performance off a distributed computing network system is largely depends on the computational performance of the working CPUs, but the number of available and active processing units is also determinant. As you can see in Table IV, the support of the larger projects is in the magnitude of 100,000 active hosts, which is not too much, considering the huge amount of desktop and notebook systems worldwide. Smartphone resources are also available in huge number, but only a small percentage of these devices are offered to any of the distributed computing projects. In my opinion, for a widely supported and successful project, it is very important to motivate the smartphone owners somehow to make their unused resources available to a distributed computing system.

Voluntary participation is based on several different reasons. Considering the running projects, most people donate their resources to a scientific research because of personal interest or involvement in the topic, maybe supplemented with competitive spirit.

A. *Supporting scientific projects*

In this case people offer unused computing time from personal computers to reach a specific, scientific goal, which generally needs heavy computational power. The main motivation for volunteering these projects is the purpose and the possible result of great importance of the research, where donors usually have emotional connection to the supported field. The most well-known, and widely supported projects are SETI@home (to detect intelligent life outside Earth), Milky-Way@home (to create a highly accurate three dimensional model of the Milky Way galaxy), Einstein@Home (to search for weak astrophysical signals from spinning neutron stars), and Folding@home (to understand protein misfolding better, which is important to fight against many serious illnesses, like Alzheimer's, Mad Cow (BSE), CJD, ALS, Huntington's, Parkinson's disease, and many cancers), which is maybe the most powerful voluntary supported distributed computing project nowadays. Despite of the limited resources, voluntary support of any scientific project with a smartphone's unused computing power only is still a noble act.

B. *Competitive spirit*

In some cases the competitive spirit could also be a motivational factor, but usually meets with some personal relation or emotional connection to the specific field. BOINC based online distributed computing networks are using credits, as a numeric measure of how much computation results the participants have contributed to in different projects. Credits also help to create statistics and comparison between computers, users, or projects. [8] To be on a top list as one of the biggest supporters of a scientific project, is a good reason for any donor or team to be proud of. Not to mention for example a possible SETI@home breakthrough, where your computer finds the first track of an intelligent alien life form.

Considering smartphones contend for being in the top 100 list of the individual donors, does not make much sense. The top users of distributed computing projects are usually system administrators or operators (maybe organizations), who can offer hundreds of computers to support a project. Because the personal use of mobile phones, this is not possible. In this case everyone has the opportunity to offer his own phone(s) for a project, but normally no one use, and can offer more than two devices at the same time. Maybe team ranking can be still interesting, but it is still much harder to establish a powerful group.

C. *Personal profit*

Rewarding donors with financial or any other benefits is quite infrequent yet. If there is a possibility to earn some money by sharing the computer's unused resources, the collected amount is typically less than the cost of the necessary electricity. A few projects offer alternative benefits, like access for the distributed resources or for example the right to name a new star your computer discovered. In case of smartphones, I think it is rather unlikely to aggregate a considerable computational capacity without a rewarding system.

VI. Expected Smartphone Donors

Using smartphone resources in a distributed computing network could be popular, because it needs less effort from the owner, compared to sharing the resources of any desktop system, and can be reached at a lower cost. In my opinion, the most promising opportunity to build a large, smartphone based or supported distributed computing network system is using rewarding donors. Not "only" with credits, but with some real value. A proper rewarding system could give a major boost to owners. Because of the limited resources of these devices, the expected reward for sharing them must be low, and acceptable for the user, and the operator of the distributed network as well. Some market segments have more potential to operate this kind of networks, because they can easily offer compensation, which looks valuable for the users, in a very low cost. In the next subsections two possible operators and some rewarding methods will be presented as examples.

A. *Mobile network operator*

Any international mobile network operator could easily motivate the subscribers to join to a provider controlled distributed computing project, offering some bonus or extra services, based on the (computing) performance of the subscriber. The reward could be a few percent discount from the next month fees, bonus minutes or short messages, or some

free data traffic using mobile broadband. For example if a donor can "earn" 5–10 MB data traffic in a month offering his smartphone resources eight hours every night, that could be motivating for many users, who have not got data subscription yet. When these users already experience the potential of mobile broadband using their free megabytes, maybe many of them will become a new data subscriber, which means new incomes to the provider. Users with data plan may not care about a few extra megabytes, but another motivation factor could be working in a longer term with this group as well. Based on the computing capacity made available in the last period (months or years) the provider can offer higher discount from the price of the user's next smartphone. Maybe granting some exclusive access to special contents is enough as well. After reaching the critical amount of clients, the provider can sell the computing capacity of his virtual supercomputer in various fields. To reach the necessary potential seems difficult at the beginning, but if we are considering multinational telecommunication companies, an international start can accelerate the expansion of active clients by aggregating capacity from each network. It is more difficult to execute, but not impossible to start (or join to) a special campaign with unique devices (or unique contents only), sold with special colors, design, and pre installed client. If someone sees one of these smartphones, will know that the owner is proud of supporting a medical research or any other specific project.

With well prepared communication, the potentials of the huge sponsorships of these telecommunication companies (like the seven year contract between Vodafone and the McLaren Mercedes Formula 1 Team) could be very well usable to collect necessary number of donors, and reach more media appearance at the same time. A distributed computing project, providing engineering calculations to improve a part of a Formula 1 car, could be very popular among fans, and after the first result, in the media as well. In this case the donors are easily and continuously can be motivated, for example with live information during the races, exclusive contents, or with the chance (based on the contributed performance) to win a VIP ticket to the next race.

B. *Google*

Android is the most popular mobile platform in the world, which deeply integrates Google services. Only in the fourth quarter of 2013, totally 758.72 million Android operated units have been sold worldwide, which means 78.4% market share in the analyzed period. [7] Based on the huge number of Android operated devices and Google users, Google has the biggest chance to build a sufficiently strong, smartphone based distributed computing network. The computing power of this virtual supercomputer could be used by Google itself, supporting any research or charitable effort with it, or can lease the virtual resources to a third party. User motivation and rewarding system can be easily developed, based on Google Play offers. Google Play is maintained by Google, and it is the primary and official application distribution platform for Android, where more than 1 million applications are published. Because of the cheap prices (most of the apps cost around 1-2 USD) with a rewarding system, users would be able to collect enough "credits" to buy a new app within a reasonable time.

VII. Conclusion

In this article a comparison has been made between the performance of smartphones and desktop/notebook computers. Even if a precise ratio is impossible to determine, it has been clearly seen that the performance of modern smartphones increased much faster last years, than the performance of any other general-purpose computer systems. For this reason smartphones could be potential resources in a distributed computing system. To reach considerable performance with these devices, traditional voluntary donation is not sufficient, a rewarding system, as an extra motivation seems necessary.

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