

# Password Cracking on Graphics Processing Unit Based Systems

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**Abstract**—Password authentication is one of the widely used methods to achieve authentication for legal users of computers and defense against attackers. There are many different ways to authenticate users of a system and there are many password cracking methods also developed. This paper proposes how best password cracking can be performed on a CPU-GPGPU based system. The main objective of this work is to project how quickly a password can be cracked with some knowledge about the computer security and password cracking if sufficient security is not incorporated to the system.

**Keywords**—GPGPU, password cracking, secret key, user authentication.

## I. INTRODUCTION

**P**ASSWORDS are designed to provide a system authentication. There are many different ways to authenticate users of a system such as log in to the system using a user name and password pair, a user can present a physical object like a key card, prove identity using biometric like a fingerprint, face recognition etc. [1].

System authentication based on password, work by comparing user supplied passwords with stored secrets. When the system administrator or attacker gets the equivalent privileges then he/she can access these secrets. Usually the passwords are not stored in plaintext. Most of the time, it is in encrypted form.

Password cracking is the process of recovering passwords from data that have been stored in or transmitted by a computer system. It can also be defined as the process of getting the normal text passwords which collides with the used hash function. A few years back, all-to-all major password breach happened for a website wherein the attacker leaked the complete list of passwords as the passwords were stored in clear text in the database with the possible security by that website [2], [4].

Brute-force cracking is one of the techniques in which a computer tries every possible password until it succeeds. Brute-force attack keeps guessing repeatedly for every possible password and checks against the available encrypted password. Here, as the password length increases, Brute-force can take huge amount of time; i.e., each additional character in a password exponentially increases the Brute-force cracking time [3], [4]. The existing hardware architectures were

dedicated to password cracking, such as Field-programmable gate array (FPGAs) that are devices containing fully programmable logic and CELL processor [6].

Password cracking is required for various reasons. Positively speaking, it might be required to recover a forgotten password or to identify the passwords that can be cracked easily so that the System Administrator can initiate necessary preventive measure. To speak negatively, an attacker gaining unauthorized access to the system. If it is encrypted password then the attacker need to verify whether a guessed password is successfully decoded from encrypted password. The cryptographic function used by the system for generating the password affects the rate, at which the password is guessed [5], [6].

An attacker can easily guess the password that is easy to remember for the authenticated user. There are various ways with which the security of the system reduces if the passwords are difficult to remember. Users may have to preserve the password by writing down on a paper or using an insecure method to store the password such as in a file.

The more stringent requirements for strengthening the passwords are to have a mix of lowercase and uppercase letters along with numbers and punctuation characters [1]. Passwords framed based on picking the first character of each word of a phrase are easily memorable as a selected password, and as hard to crack as randomly generated passwords. Another good way is to have a password is by combining two unrelated words.

The effort it has taken to crack the password decides the strength of a password. One can increase the length of the password for a cracking attempt to take more time. This results in more difficulty in recovering the password.

It is going to be great time consuming process if you rely wholly on the general purpose CPU based system to recover the password. Here we propose how best password cracking can be performed on a CPU-GPGPU based system [7].

The computational power of General-Purpose computation on Graphics Processing Units (GPGPUs) is exploited in our work. Computationally intensive tasks are solved using GPGPU where parallel computation is needed. Computational work is allocated in parallel operations among large number of cores within the GPGPU. In other words, data-parallel computations are highly supported by GPGPUs. Each program can be executed on many data elements in parallel. Here sophisticated flow control is not required among the separate threads.

Computation on GPGPU is based on the principle of data parallelism. Individual thread is processing each data element

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of a task. To speed up computation with GPGPUs, data-parallel programming model can be used that needs to process a large data set. This approach is used for generating such huge combinations of possible passwords. As a result, performance gain can be achieved by using different Work Item and Work Group distributions on GPGPU computation. Parallel processing suits very much for password cracking since the input data can be distributed uniformly over the group of concurrent threads. These threads can perform the same operations on different set of data until a matching password is identified, concurrently and independently.

In this paper, we present how easily the password can be cracked if enough security is not given to the system. Paper also talks on how an attacker can crack the password when he/she have the ability to attempt to log in to the system using a user name and password pair. Here we have assumed that an attacker has access to the password file, whichever format they are stored on the system for password crack work.

## II. METHODOLOGY

Normally the authenticated users will have the password with a mix of uppercase and lowercase letters along with numbers and punctuation characters. Brute-force cracking procedure has been implemented on a machine having the specification as Intel i3 dual core CPU with operating frequency 1.70 GHz, 4 GB RAM, 64-bit Windows 8.1 and 1TB HDD. The system is supporting NVIDIA GeForce 820M GPU, 96 cores; 2GB dedicated RAM with OpenCL support.

Open Computing Language (OpenCL) is used to ease the parallel programming methodology when developing applications for heterogeneous systems. OpenCL also addresses the current trend to increase the number of cores on a given architecture.

OpenCL framework supports execution on multi-core CPU and GPGPUs. There are many more heterogeneous devices supported by OpenCL framework which is seldom of interest to our work. The heterogeneous architecture has already supported to cover a wide range of approaches to extract parallelism and efficiency from memory systems and instruction streams. OpenCL has standard abstractions and interfaces that allow programmers to develop the application within which execution can occur on a rich set of heterogeneous devices [8].

Here a parallel code developed [9]-[12] in OpenCL can generate a certain length of password based upon all permutations and combinations of uppercase and lowercase letters along with numbers and punctuation characters.

The code is written such that it can generate all combination of two character length passwords, three character length passwords and so on up to  $n$  character length passwords containing uppercase and lowercase letters along with numbers and punctuation characters.

In this paper, we have considered the generation of password with maximum length 4 and this password can contain various combinational mix of uppercase and lowercase letters along with numbers and punctuation characters from maximum of 52 character set.

Even though the generation of passwords of different lengths is sequential, the generation of passwords with all permutations and combinations for a certain length happens in parallel. In our proposed algorithm, this is how we have reduced Brute-force cracking time greatly in contrast with each additional character in a password that exponentially increasing the cracking time on CPU based system [2], [5].

This Brute-force method further could be enhanced to crack the encrypted password if the secret key is known. Attacker now can easily crack an authenticated user's password by searching for the matching combination in authenticated encrypted password file of the system.

Absolutely in no time attacker can decode an authenticated password of a user if sufficient security is not incorporated to the system.

## III. RESULT

Our experiment tests the power of parallel computing on GPGPU against the computations needed by Brute-force technique to generate the two, three and four character length passwords containing uppercase and lowercase letters. This also explores the performance gain which can be achieved by using different Work Item and Work Group distributions on the GPGPU.

Figs. 1 (a)-(c) show partial snapshots of two, three and four character length passwords generated. Power of parallel computing analysis also has been done for different Work Item and Work Group creation.

aa	ba	ca	da	ea	fa	ga	ha	ia	ja	ka	la	ma
na	oa	pa	qa	ra	sa	ta	ua	va	wa	xa	ya	
za	Aa	Ba	Ca	Da	Ea	Fa	Ga	Ha	Ia	Ja	Ka	La
La	Ma	Na	Oa	Pa	Qa	Ra	Sa	Ta	Ua	Va	Wa	
Xa	Ya	Za	ab	bb	cb	db	eb	fb	gb	hb	ib	
jb	kb	lb	mb	nb	ob	pb	qb	rb	sb	tb	ub	
vb	wb	xb	yb	zb	Ab	Bb	Cb	Db	Eb	Fb	Gb	
Hb	Ib	Jb	Kb	Lb	Mb	Nb	Ob	Pb	Qb	Rb	Sb	
Tb	Ub	Vb	Wb	Xb	Yb	Zb	ac	bc	cc	dc	ec	
fc	gc	hc	ic	jc	kc	lc	mc	nc	oc	pc	qc	
rc	sc	tc	uc	vc	wc	xc	yc	zc	Ac	Bc	Cc	
Dc	Ec	Fc	Gc	Hc	Ic	Jc	Kc	Lc	Mc	Nc	Oc	
Pc	Qc	Rc	Sc	Tc	Uc	Vc	Wc	Xc	Yc	Zc	ad	
bd	cd	dd	ed	fd	gd	hd	id	jd	kd	ld	md	
nd	od	pd	qd	rd	sd	td	ud	vd	wd	xd	yd	
zd	Ad	Bd	Cd	Dd	Ed	Fd	Gd	Hd	Id	Jd	Kd	
Ld	Md	Nd	Od	Pd	Qd	Rd	Sd	Td	Ud	Vd	Wd	
Xd	Yd	Zd	ae	be	ce	de	ee	fe	ge	he	ie	
je	ke	le	me	ne	oe	pe	qe	re	se	te	ue	
ve	we	xe	ye	ze	Ae	Be	Ce	De	Ee	Fe	Ge	
He	Ie	Je	Ke	Le	Me	Ne	Oe	Pe	Qe	Re	Se	
Te	Ue	Ve	We	Xe	Ye	Ze	af	bf	cf	df	ef	
ff	gf	hf	if	jf	kf	lf	mf	nf	of	pf	qf	
rf	sf	tf	uf	vf	wf	xf	yf	zf	Af	Bf	Cf	
Df	Ef	Ff	Gf	Hf	If	Jf	Kf	Lf	Mf	Nf	Of	
Pf	Qf	Rf	Sf	Tf	Uf	Vf	Wf	Xf	Yf	Zf	ag	

Fig. 1 (a) Partial list of all combinations of two character length passwords containing uppercase and lowercase letters

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aaa baa caa daa eaa faa gaa haa iaa jaa kaa laa maa
naa oaa paa qaa raa saa taa uaa vaa waa xaa yaa
zaa Aaa Baa Caa Daa Eaa Faa Gaa Haa Iaa Jaa Kaa
Laa Maa Naa Oaa Paa Qaa Raa Saa Taa Uaa Vaa Waa
Xaa Yaa Zaa aba bba cba dba eba fba gba hba iba
jba kba lba mba nba oba pba qba rba sba tba uba
vba wba xba yba zba Aba Bba Cba Dba Eba Fba Gba
Hba Iba Jba Kba Lba Mba Nba Oba Pba Qba Rba Sba
Tba Uba Vba Wba Xba Yba Zba aca bca cca dca eca
fca gca hca ica jca kca lca mca nca oca pca qca
rca sca tca uca vca wca xca yca zca Aca Bca Cca
Dca Eca Fca Gca Hca Ica Jca Kca Lca Mca Nca Oca
Pca Qca Rca Sca Tca Uca Vca Wca Xca Yca Zca ada
bda cda dda eda fda gda hda ida jda kda lda mda
nda oda pda qda rda sda tda uda vda wda xda yda
zda Ada Bda Cda Dda Eda Fda Gda Hda Ida Jda Kda
Lda Mda Nda Oda Pda Qda Rda Sda Tda Uda Vda Wda
Xda Yda Zda aea bea cea dea eea fea gea hea iea
jea kea lea mea nea oea pea qea rea sea tea uea
vea wea xea yea zea Aea Bea Cea Dea Eea Fea Gea
Hea Iea Jea Kea Lea Mea Nea Oea Pea Qea Rea Sea
Tea Uea Vea Wea Xea Yea Zea afa bfa cfa dfa efa
ffa gfa hfa ifa jfa kfa lfa mfa nfa ofa pfa qfa
rfa sfa tfa ufa vfa wfa xfa yfa afa Bfa Cfa
Dfa Efa Ffa Gfa Hfa Ifa Jfa Kfa Lfa Mfa Nfa Ofa
Pfa Qfa Rfa Sfa Tfa Ufa Vfa Wfa Xfa Yfa Zfa aga
    
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Fig. 1 (b) Partial list of all combinations of three character length passwords containing uppercase and lowercase letters

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aaaa baaa caaa daaa eaaa faaa gaaa haaa iaab jaab kaab laab maab
naaa oaaa paab qaab raab saab taab uaab vaab waab xaab yaab
zaaa Aaaa Baaa Caaa Daaa Eaaa Faaa Gaaa Haaa Iaaa Jaaa Kaaa
Laaa Maaa Naaa Oaaa Paaa Qaaa Raaa Saaa Taaa Uaaa Vaaa Waaa
Xaaa Yaaa Zaaa abaa bbaa cbaa dbaa ebaa fbaa gbaa hbaa ibaa
jbaa kbaa lbaa mbaa nbaa obaa pbaa qbaa rbaa sbaa tbaa ubaa
vbaa wbaa xbaa ybaa zbaa Abaa Bbaa Cbaa Dbaa Ebaa Fbaa Gbaa
Hbaa Ibaa Jbaa Kbaa Lbaa Mbaa Nbaa Obaa Pbaa Qbaa Rbaa Sbaa
Tbaa Ubaa Vbaa Wbaa Xbaa Ybaa Zbaa acaa bcaa ccaa dcaa ecaa
fcaa gcaa hcaa icaa jcaa kcaa lcaa mcaa ncaa ocaa pcaa qcaa
rcaa scaa tcaa ucaa vcaa wcaa xcaa ycaa zcaa Acaa Bcaa Ccaa
Dcaa Ecaa Fcaa Gcaa Hcaa Icaa Jcaa Kcaa Lcaa Mcaa Ncaa Ocaa
Pcaa Qcaa Rcaa Scaa Tcaa Ucaa Vcaa Wcaa Xcaa Ycaa Zcaa adaa
bdaa cdaa ddaa edaa fdaa gdaa hdaa idaa jdaa kdaa ldaa mdaa
nda aada pdaa qdaa rdaa sdaa tdaa udaa vdaa wdaa xdaa ydaa
zdaa Adaa Bdaa Cdaa Ddaa Edaa Fdaa Gdaa Hdaa Idaa Jdaa Kdaa
Ldaa Mdaa Ndaa Odaa Pdaa Qdaa Rdaa Sdaa Tdaa Udaa Vdaa Wdaa
Xdaa Ydaa Zdaa aaaa beaa ceaa deaa eaaa feaa geaa heaa iaaa
jeaa keaa leaa meaa neaa oaaa paab qaab raab saab taab uaab
vaab waab xaab yaab zbaa Abaa Bbaa Cbaa Dbaa Ebaa Fbaa Gbaa
Hbaa Ibaa Jbaa Kbaa Lbaa Mbaa Nbaa Obaa Pbaa Qbaa Rbaa Sbaa
Tbaa Ubaa Vbaa Wbaa Xbaa Ybaa Zbaa afaa bfaa cfaa dfaa efaa
ffaa gfaa hfaa ifaa jfaa kfaa lfaa mfaa nfaa ofaa pfaa qfaa
rfaa sfaa tfaa ufaa vfaa wfaa xfaa yfaa afaa Bfaa Cfaa
Dfaa Efaa Ffaa Gfaa Hfaa Ifaa Jfaa Kfaa Lfaa Mfaa Nfaa Ofaa
Pfaa Qfaa Rfaa Sfaa Tfaa Ufaa Vfaa Wfaa Xfaa Yfaa Zfaa agaa
bgaa cgaa dgaa egaa fgaa ggaa hga a igaa jgaa kgaa lgaa mgaa
ngaa ogaa pgaa qgaa rgaa sgaa tgaa ugaa vgaa wgaa xgaa ygaa
zgaa Agaa Bgaa Cgaa Dgaa Egaa Fgaa Ggaa Hgaa Igaa Jgaa Kgaa
Lgaa Mgaa Ngaa Ogaa Pgaa Qgaa Rgaa Sgaa Tgaa Ugaa Vgaa Wgaa
Xgaa Ygaa Zgaa ahaa bhaa cha a dhaa ehaa fhaa ghaa hhaa ihaa
jhaa khaa lhaa mhaa nhaa ohaa pha a rhaa sha a tha a uhaa
vhaa wha a xha a yha a zha a Ahaa Bhaa Cha a Dhaa Ehaa Fhaa Ghaa
Hhaa Ihaa Jhaa Khaa Lhaa Mhaa Nhaa Ohaa Pha a Qhaa Rhaa Sha a
Tha a Uhaa Vhaa Wha a Xhaa Yha a Zha a aiaa biaa ciaa diaa eiaa
fiaa giaa hiaa iaab jiaa kiaa liaa mia a niaa oiaa piaa qiaa
riaa siaa tiaa uiaa viaa wiaa xiaa yiaa ziaa Aiaa Biaa Ciaa
    
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Fig. 1 (c) Partial list of all combinations of four character length passwords containing uppercase and lowercase letters

Fig. 2 (a) gives the details on the amount of computational time taken by the Kernel and also by the whole program. This computational time is to generate all possible combinations of two, three and four character length passwords with Work Item size = 1 and Work Group size = 52.

In Fig. 2 (b), the computational time by the Kernel code and the whole program is considered with Work Item size = 13 and Work Group size = 4. Fig. 2 (c) enunciates the computational time by the Kernel and the whole program with Work Item size = 26 and Work Group size = 2.

It has been observed that the amount of time taken to run the whole program is almost identical in all the cases. However, it is the rate at which the generation of all possible combination of passwords matters.

It is strongly to be noted on the amount of time taken for the kernel code running on the GPGPU of a computer. A total of 7454928 numbers of two, three and four character length passwords has been generated by the GPGPU in a very short time.

While generating the passwords, the passwords of different lengths are sequential. The generation of passwords with all permutations and combinations of characters for a certain length happens in parallel. In our proposed algorithm, this is how we have reduced Brute-force cracking time greatly in contrast with each additional character in a password that exponentially increasing the cracking time on CPU based system. This kernel time is reduced further to accelerate the number of password generation by increasing the Work item and hence reducing Work Group.



Fig. 2 (a) Time taken by the Kernel and the whole program with Work Item size = 1 and Work Group size = 52



Fig. 2 (b) Time taken by the Kernel and the whole program with Work Item size = 13 and Work Group size = 4



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C:\Users\User-PC\Documents\Visual Studio 2012\Projects\opencil\cpencl\Debu...
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Global Size = 52 Local Size = 26
Number Of Letter Used = 52
Maximun Word Length = 4
Total Number Of Words Generated = 745428
Time taken to execute the KERNEL = 0.088 Seconds
Time taken to execute the whole program = 12.481 Seconds
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Fig. 2 (c) Time taken by the Kernel and the whole program with Work Item size = 26 and Work Group size = 2

The amount of time in cracking a password depends on password strength and the details of how the password is stored. In general, the total number of passwords generated by the GPGPU is calculated as:

$$L^m + L^{m+1} + \dots + L^M$$

where  $L$  is the number of characters set,  $m$  minimum length and  $M$  is the maximum length of the password generated.

#### IV. CONCLUSION

Efficient password cracking is a trade-off between success rate and speed. In our paper, we described the one of the technique of password cracking. We have shown that how GPGPUs are efficient in a system to generate all the possible combination of passwords. It has been explained how Brute-force method can become most feasible approach towards password cracking using CPU-GPGPU based system.

In our work, we analyzed the effect of parallelism on execution of kernel on GPGPU. We proposed how best password cracking can be performed on a CPU-GPGPU based system. If sufficient security is not incorporated to the system, then it is shown how quickly a password can be cracked with some knowledge about the computer security.

The result provided here is for the password of length of 4 characters. The same can be extended to passwords of any length without compromising over the time taken for the password generation in contrast with the CPU based system.

The best method of preventing a password from being cracked is to ensure that attackers cannot get access even to the encrypted password. Encrypted passwords should be stored in the file which is accessible only to programs running with system privileges. This makes it harder for an attacker to obtain the encrypted passwords. Unfortunately, many common network protocols transmit passwords in clear text or use weak challenge/response schemes.

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