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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

PASSWORDS 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.

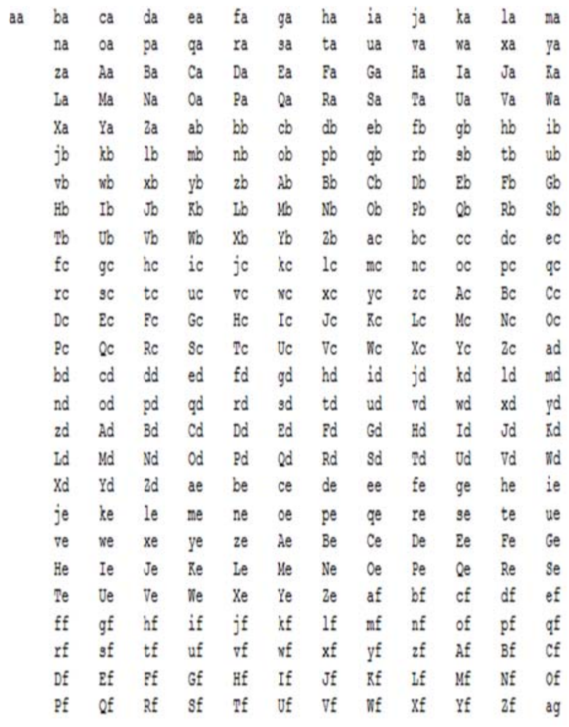
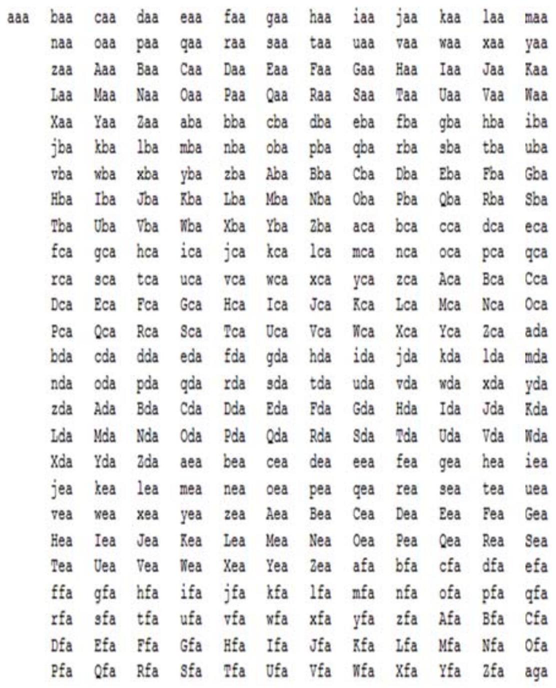
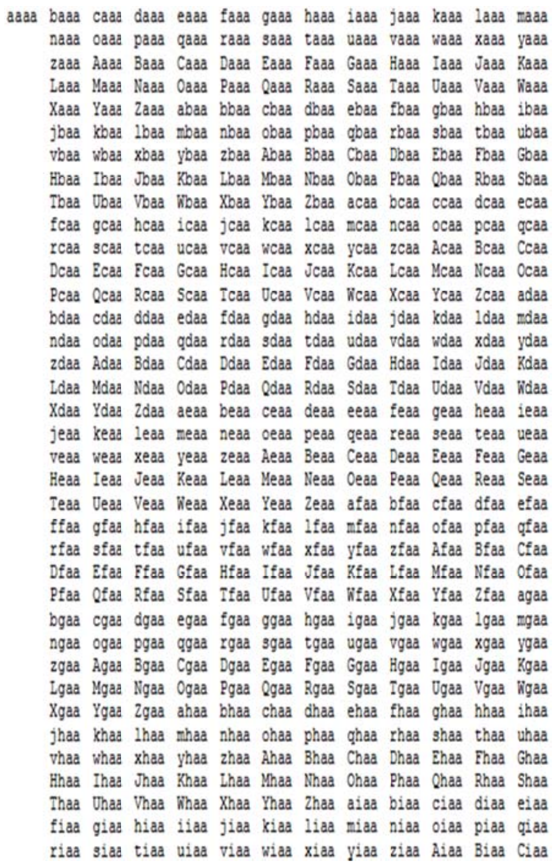

```
aa  ba  ca  da  ea  fa  ga  ha  ia  ja  ka  la  ma
    na  oa  pa  qa  ra  sa  ta  ua  va  wa  xa  ya
    za  Aa  Ba  Ca  Da  Ea  Fa  Ga  Ha  Ia  Ja  Ka
    La  Ma  Na  Oa  Pa  Qa  Ra  Sa  Ta  Ua  Va  Wa
    Xa  Ya  Za  ab  bb  cb  db  eb  fb  gb  hb  ib
    jb  kb  lb  mb  nb  ob  pb  qb  rb  sb  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



```
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  zfa  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
```

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



```
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 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
     ndaa odaa 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 aeaa beaa ceaa deaa eeaa feaa geaa heaa ieaa
     jeaa keaa leaa meaa neaa oeaa peaa qeaa reaa seaa teaa ueaa
     veaa weaa xeaa yeaa zeaa Aeaa Beaa Ceaa Deaa Eeaa Feaa Geaa
     Heaa Ieaa Jeaa Keaa Leaa Meaa Neaa Oeaa Peaa Qeaa Reaa Seaa
     Teaa Ueaa Veaa Weaa Xeaa Yeaa Zeaa 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 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 hgaa 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 chaa dhaa ehaa fhaa ghaa hhaa ihaa
     jhaa khaa lhaa mhaa nhaa ohaa phaa qhaa rhaa shaa thaa uhaa
     vhaa whaa xhaa yhaa zhaa Ahaa Bhaa Chaa Dhaa Ehaa Fhaa Ghaa
     Hhaa Ihaa Jhaa Khaa Lhaa Mhaa Nhaa Ohaa Phaa Qhaa Rhaa Shaa
     Thaa Uhaa Vhaa Whaa Xhaa Yhaa Zhaa aiaa biaa ciaa diaa eiaa
     fiaa giaa hiaa iiaa jiaa kiaa liaa miaa 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

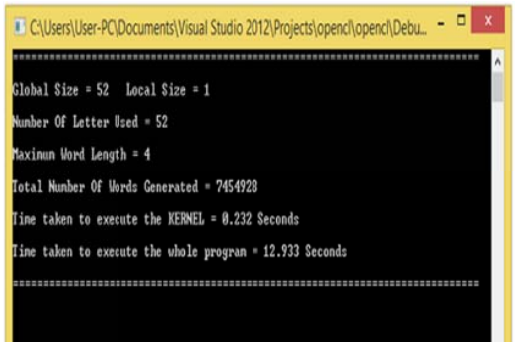
Fig. 2 (a) gives the details on the amount of computational time taken by the Kernel and also by the whole program. This computational time is to generate all possible combinations of two, three and four character length passwords with Work Item size = 1 and Work Group size = 52.

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.

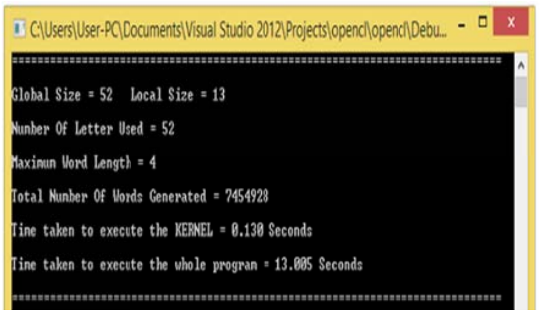
While generating the passwords, the passwords of different lengths are sequential. The generation of passwords with all permutations and combinations of characters for a certain length happens in parallel. In our proposed algorithm, this is how we have reduced Brute-force cracking time greatly in contrast 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.



C:\Users\User-PC\Documents\Visual Studio 2012\Projects\opencl\opencl\Debu...

```
==========================================================================
Global Size = 52   Local Size = 1
Number Of Letter Used = 52
Maximum Word Length = 4
Total Number Of Words Generated = 7454928
Time taken to execute the KERNEL = 0.232 Seconds
Time taken to execute the whole program = 12.933 Seconds
==========================================================================
```

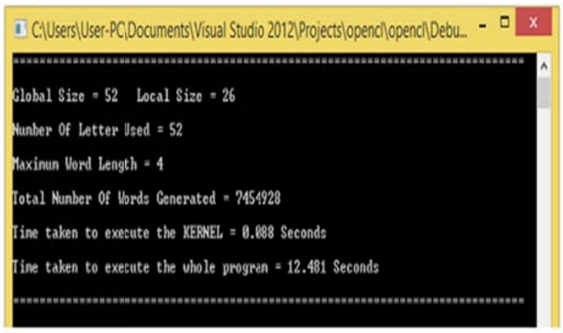
Fig. 2 (a) Time taken by the Kernel and the whole program with Work Item size = 1 and Work Group size = 52



C:\Users\User-PC\Documents\Visual Studio 2012\Projects\opencl\opencl\Debu...

```
==========================================================================
Global Size = 52   Local Size = 13
Number Of Letter Used = 52
Maximum Word Length = 4
Total Number Of Words Generated = 7454928
Time taken to execute the KERNEL = 0.130 Seconds
Time taken to execute the whole program = 13.005 Seconds
==========================================================================
```

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


C:\Users\User-PC\Documents\Visual Studio 2012\Projects\opencl\opencl\Debu...

```
================================================================================

Global Size = 52   Local Size = 26

Number Of Letter Used = 52

Maximum Word Length = 4

Total Number Of Words Generated = 7454928

Time taken to execute the KERNEL = 0.088 Seconds

Time taken to execute the whole program = 12.481 Seconds

================================================================================
```

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:

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

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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