Probabilistic Passphrase Cracking

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balsa
chew
pure
swan
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What are passphrases?

- balsa
- chew
- pure
- swan

- balsa chew pure swan
- I have got a nice bike
Prior Work

• 2012 Labrande
  Hybrid dictionary attack

• 2016 Sparell and Simovits
  Markov chains

• 2017 Gaastra, Gijtenbeek and Gommans
  Using lyrics and famous quotes
Research Question

How can software efficiently generate likely passphrases, to be used in passphrase cracking?

- Efficient:
  - Computational power
  - RAM
  - Storage

- Likely:
  - Results
Contribution

• Implement a new method

• Compare different methods
  – Make previous work directly comparable
Hybrid dictionary attack

- Reproduced Labrande’s work
  - Training dataset
  - Effectiveness comparison

- Dictionary of phrases + sets of rules
  - Lowercase all, remove spaces, etc.
Probabilistic Method Selection

- Markov chains
done by Sparell and Simovits
- Probabilistic Context-Free Grammar
  applied to passwords successfully
- N-grams
  popular in text prediction
Context-Free Grammar

\[ S \rightarrow NP \ VP \]
\[ NP \rightarrow Det \ N \mid W \]
\[ VP \rightarrow V \ NP \]
\[ W \rightarrow I \mid he \mid she \mid Joe \]
\[ Det \rightarrow a \mid the \mid my \mid his \]
\[ N \rightarrow elephant \mid cat \mid jeans \mid suit \]
\[ V \rightarrow kicked \mid followed \mid shot \]

- I followed Joe
- a cat shot my elephant
Probabilistic Context-Free Grammar

- $NP \rightarrow 0.7(Det \, N) \mid 0.3(W)$

- Generate probabilities and rules based on texts
  - Word classification database
N-grams

- „have we lost or have we won“ n=2
  - 2 have we
  - 1 we lost
  - 1 lost or
  - 1 or have
  - 1 we won

→ have we won
N-grams

- Generated weighted statistics from:
  - Wikipedia articles
  - Previously cracked passphrases

- Cracking by taking the most frequently occurring n-gram and finding continuations
Results
Effectiveness

• Hybrid dictionary (Labrande)
  – \textbf{4.2M} phrases of Korelogic (\textbf{200k} of ≥16 characters)

• Hybrid dictionary (ours)
  – \textbf{2.3M} phrases of Korelogic (\textbf{147k} of ≥16 characters)
  – \textbf{1.3M} phrases of LinkedIn (\textbf{13k} of ≥16 characters)

• Markov chains
  – \textbf{25k} phrases of LinkedIn (\textbf{384} of ≥16 characters)

• N-grams
  – \textbf{835k} phrases of Korelogic (\textbf{33k} of ≥16 characters)
  – \textbf{482k} phrases of LinkedIn (\textbf{4k} of ≥16 characters)
Results
Efficiency

- Hybrid dictionary
  - Speed: >10 000 000 pps (phrases per second)
  - Storage: medium (690MiB)
- Markov chains
  - Speed: 2 500–22 500 pps
  - Storage: unknown
- N-grams
  - Speed: 3 300 000 pps
  - Storage: low-medium (47-464MiB)
Conclusions

- Hybrid dictionary is efficient and effective
- N-grams most effective when length of phrase $\leq n$
Future work

- Better language modeling using n-grams
- Probabilistic Context-Free Grammar
- Neural Networks
Thank you

- Thanks to Radically Open Security

- See our git repository for GPLv3 licensed:
  - N-gram phrase generator & models (n=2 and n=3)
  - Phrase dictionary & rules
  - Slides and preview of the paper
    github.com/radicallyopensecurity/passphrase-cracking

- Questions?