On the Forensic Validity of Approximated Audit Logs

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Sneha Gaur, Wajih Ul Hassan, and Adam Bates

University of Illinois at Urbana-Champaign

Audit Logs are Invaluable

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- Records history of executed events
  - Kernel-level frameworks track application syscalls

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[1] Carbon Black. 2018. Global Incident Response Threat Report. https://www. carbonblack.com/global-incident-response-threat-report/november-2018/

Audit Logs are Invaluable
… but Burdensome

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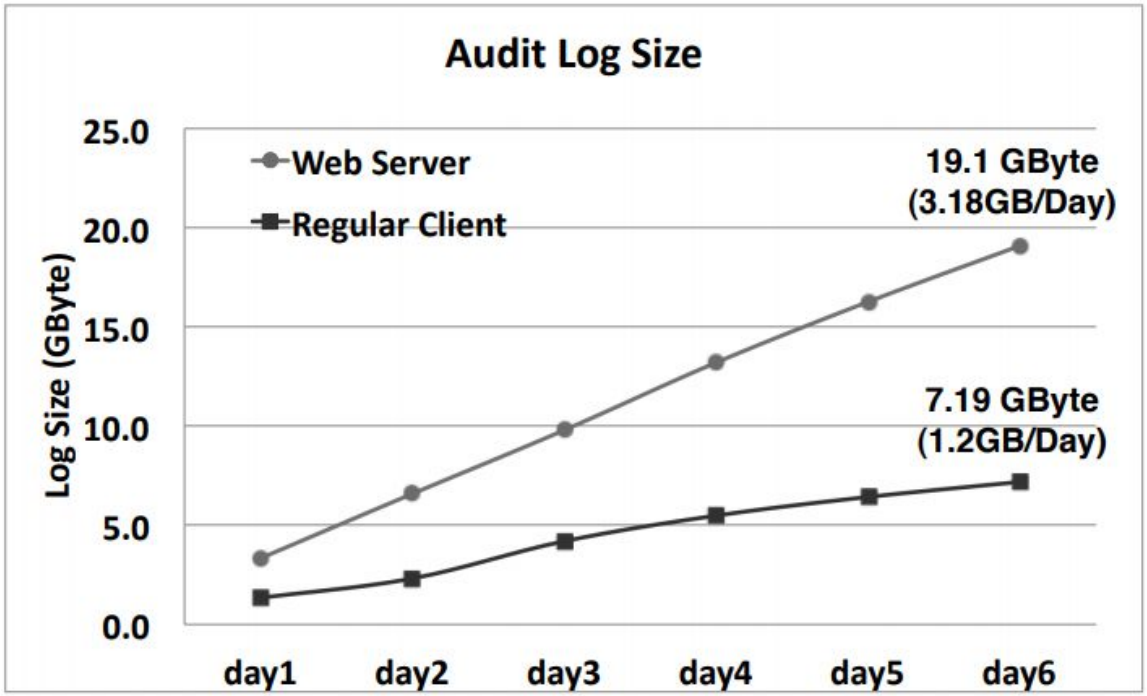

[1] Carbon Black. 2018. Global Incident Response Threat Report. https://www. carbonblack.com/global-incident-response-threat-report/november-2018/

[2] Lee et. al. LogGC: Garbage Collecting Audit Log. In Proceedings of the 2013 ACM SIGSAC conference on Computer & communications security (CCS '13)

Audit Log Reduction Techniques

Insight: The entire audit log is not often required

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  1: <Proc A, t_001, send, server.com>
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Original Log

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The same conclusion is reached with either log

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Conclusions may differ!

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Original Log **Approximated Log**

Conclusions may differ!

How much information is kept for arbitrary goals under different threat models?

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Formalizing Forensic Metrics

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Provenance Graph

Nodes: System Objects

Edges: Causal Events

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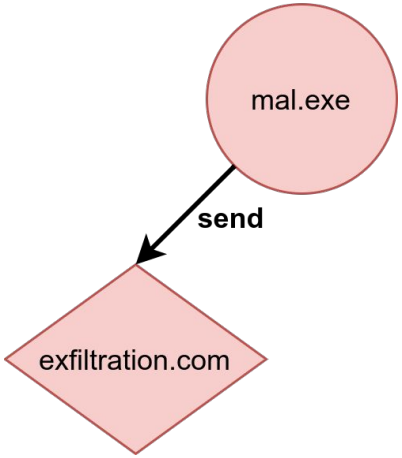

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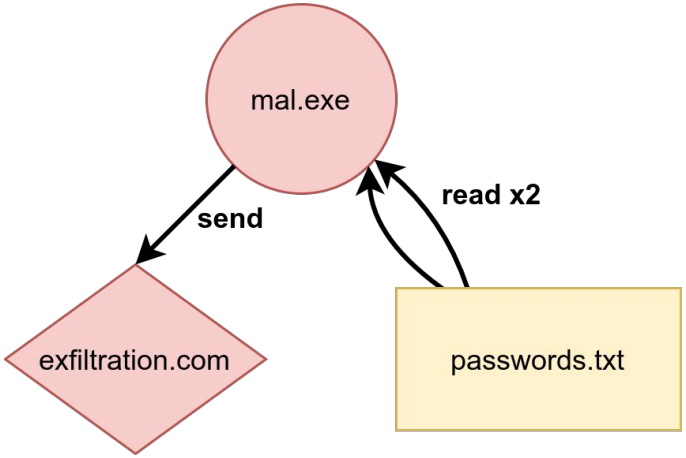

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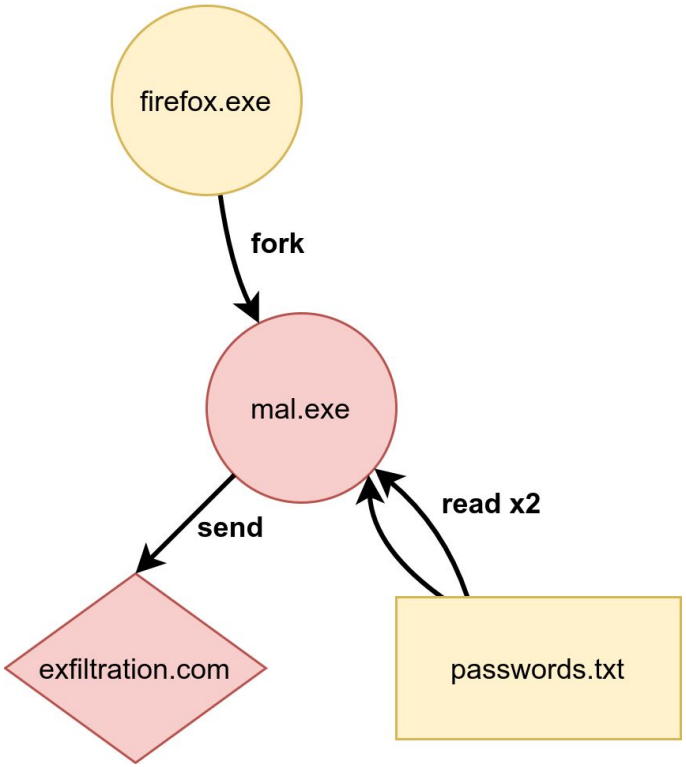

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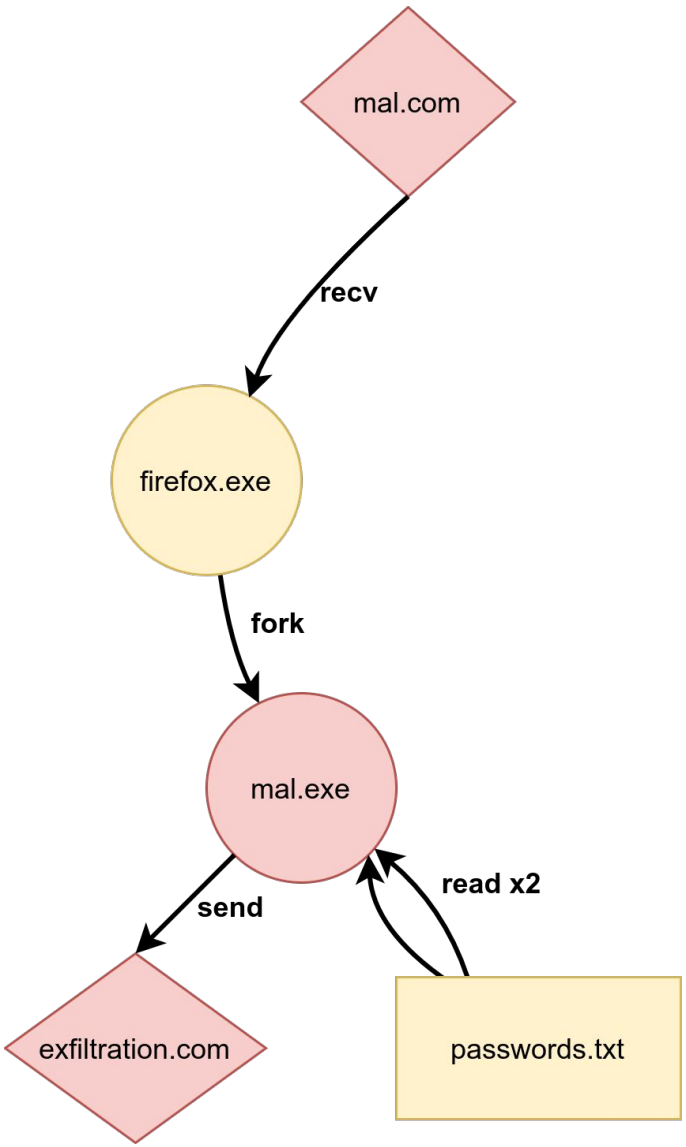

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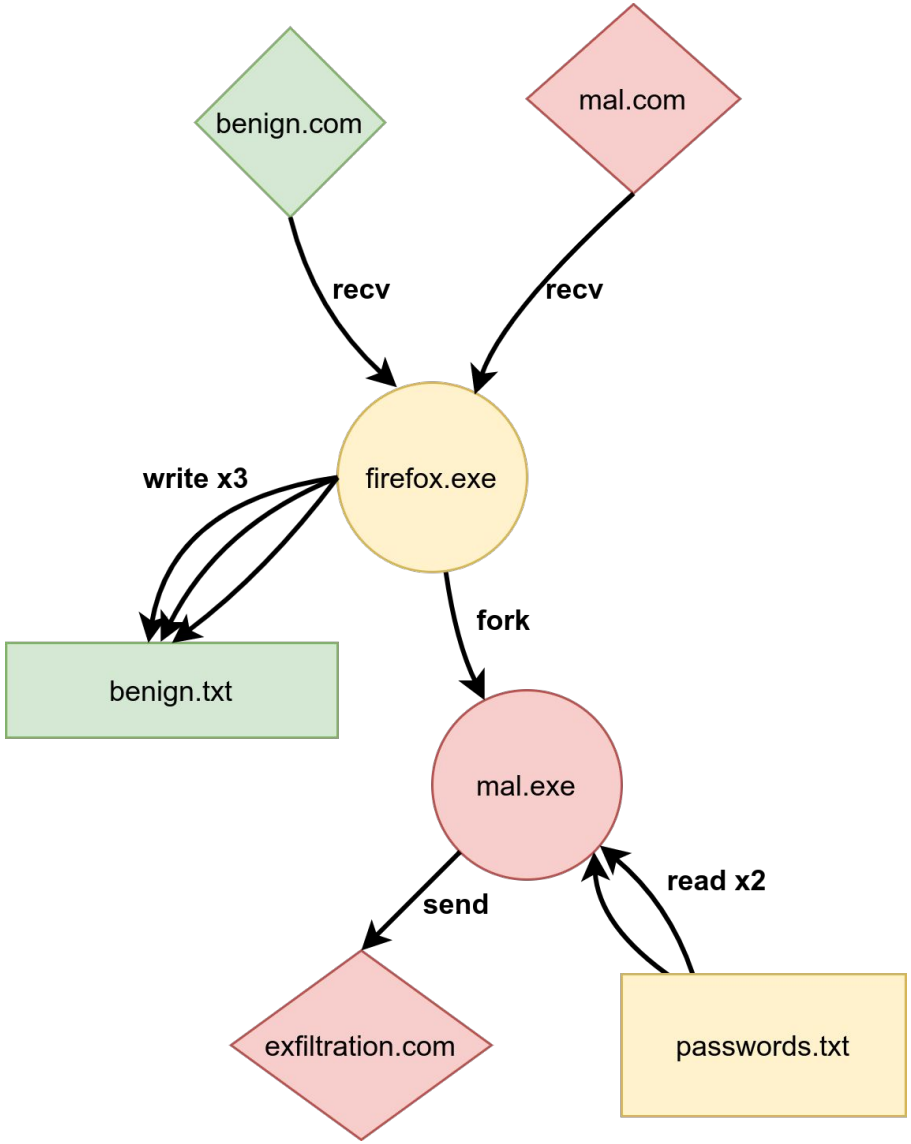

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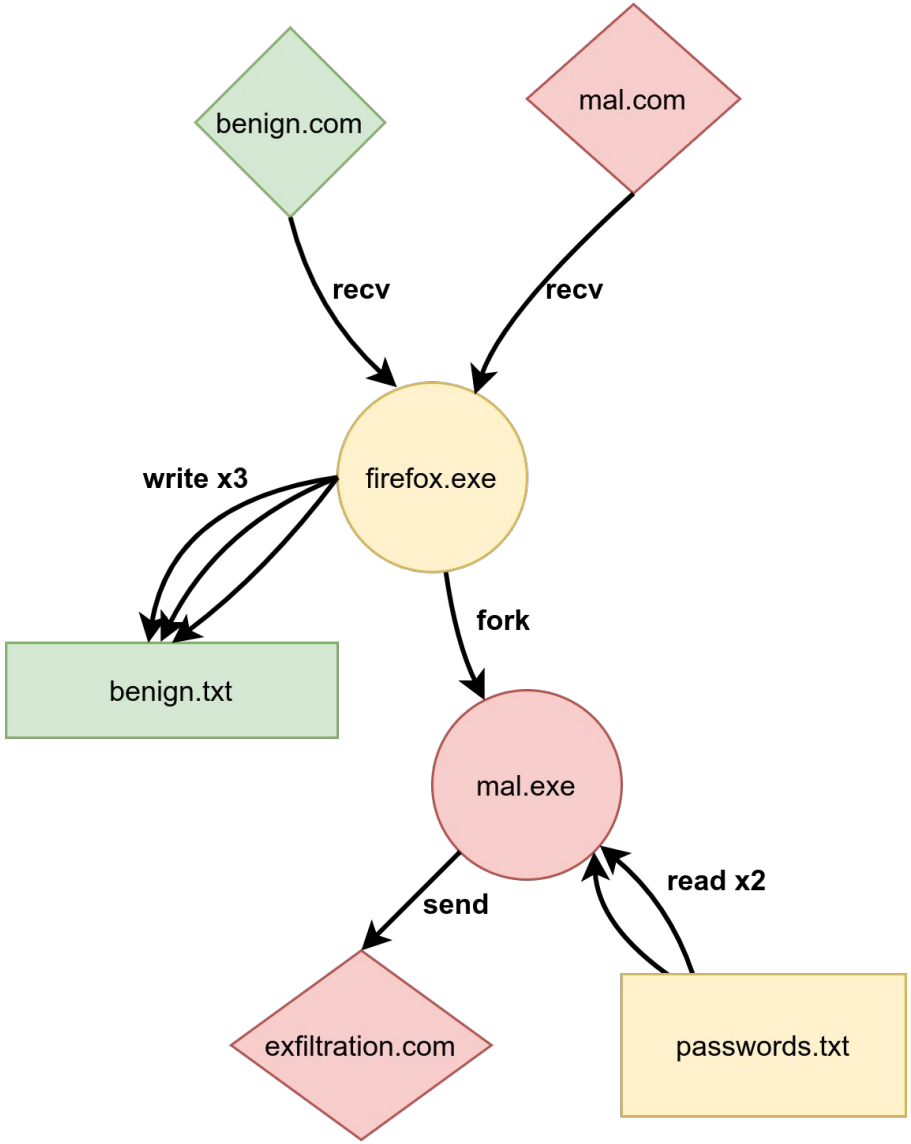

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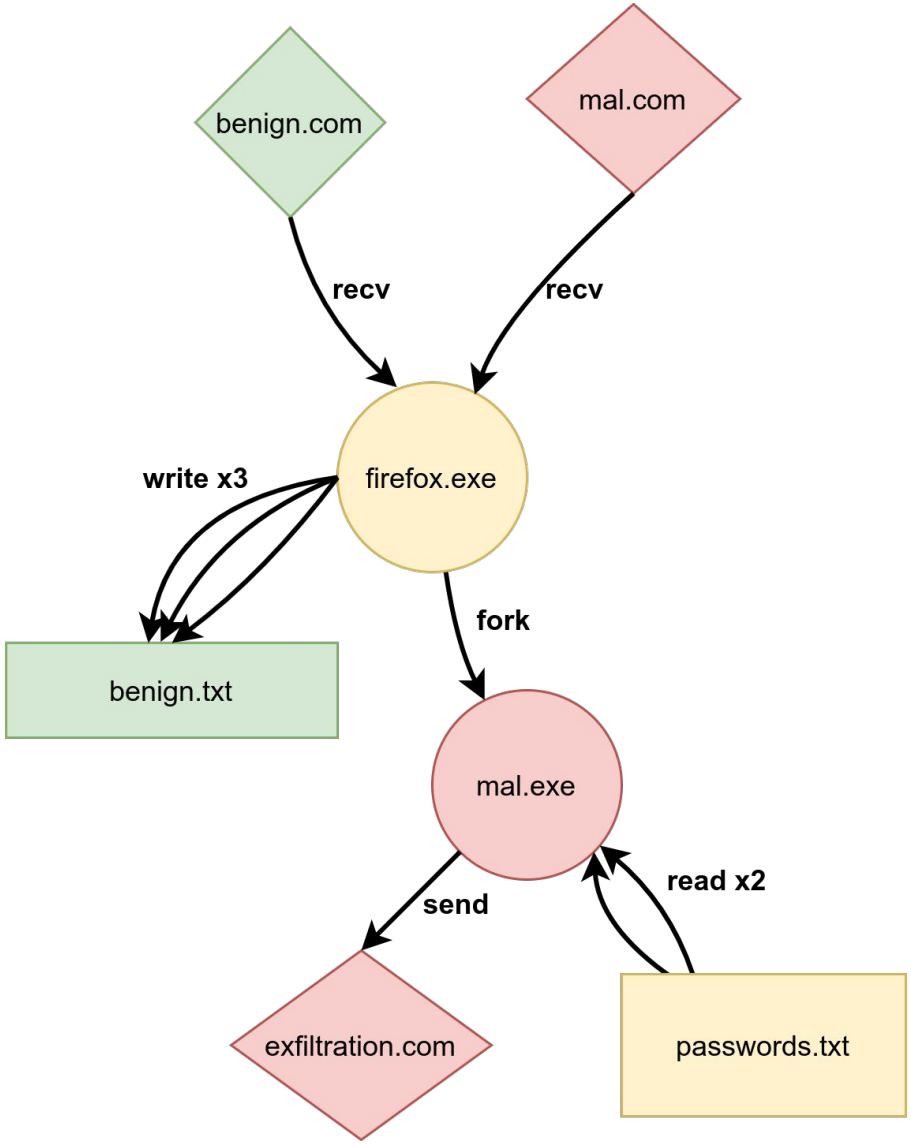
Lossless

Threat Model:
Diverges from system level abstractions

Preserves:
All Information



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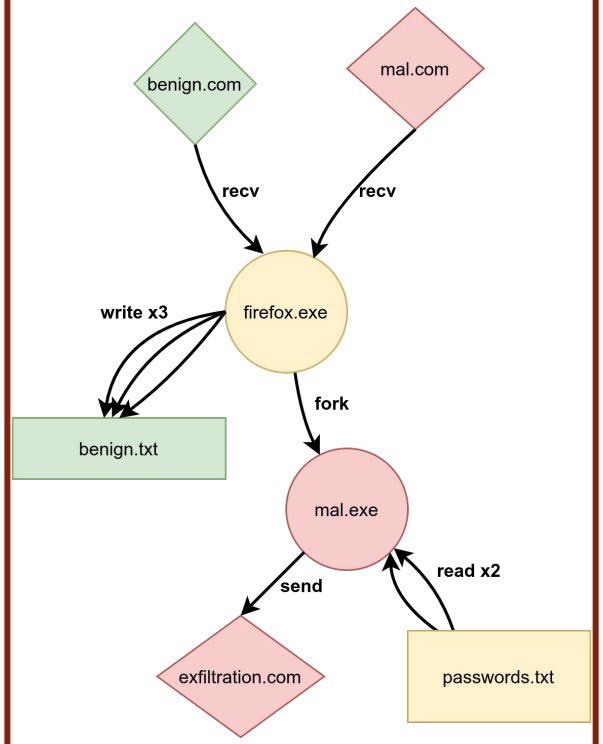

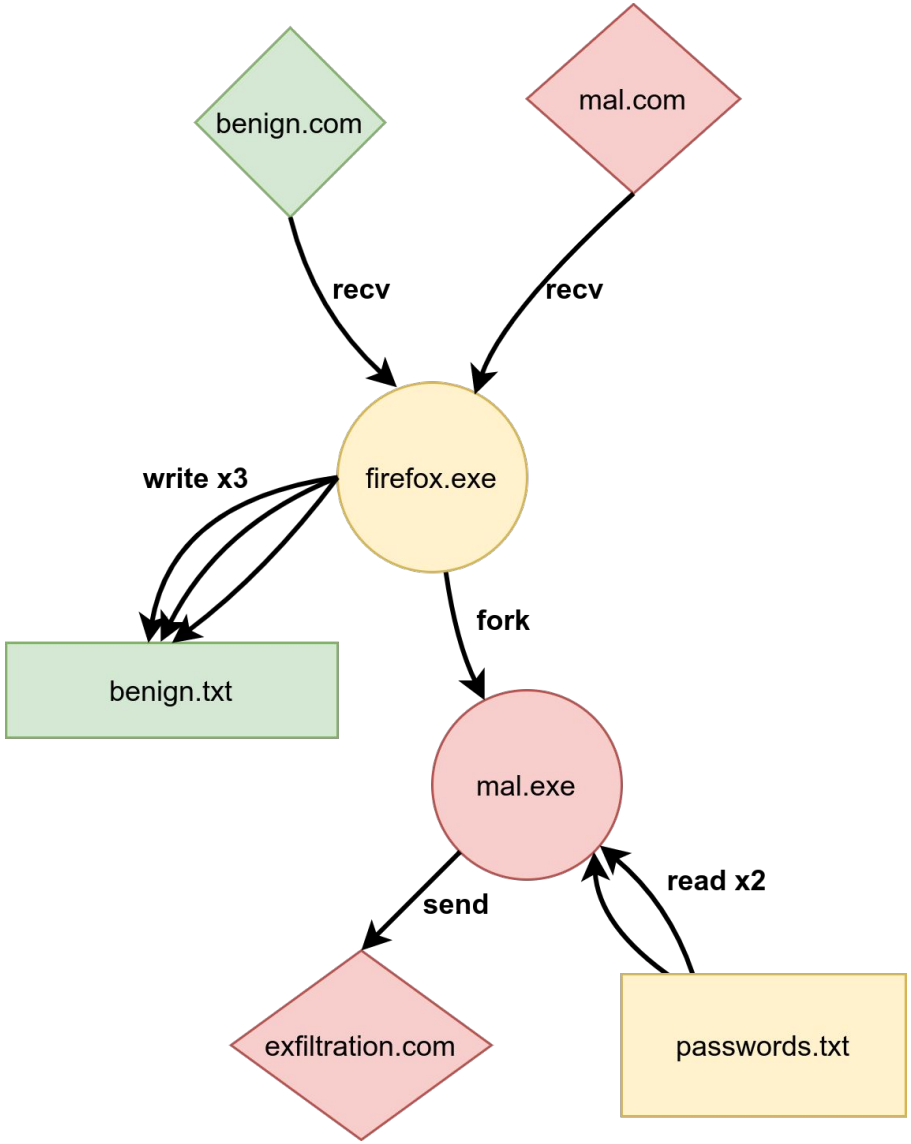

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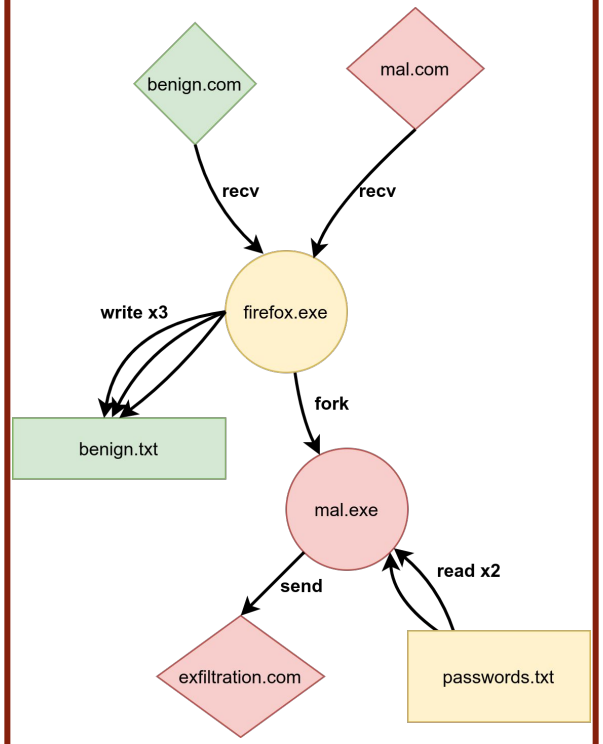

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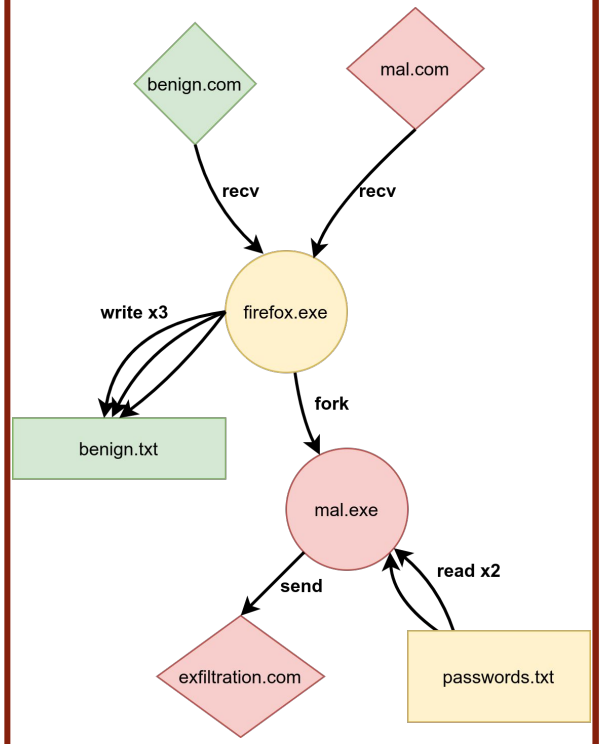

Causality-Preserving

(based on Xu et. al.[1])

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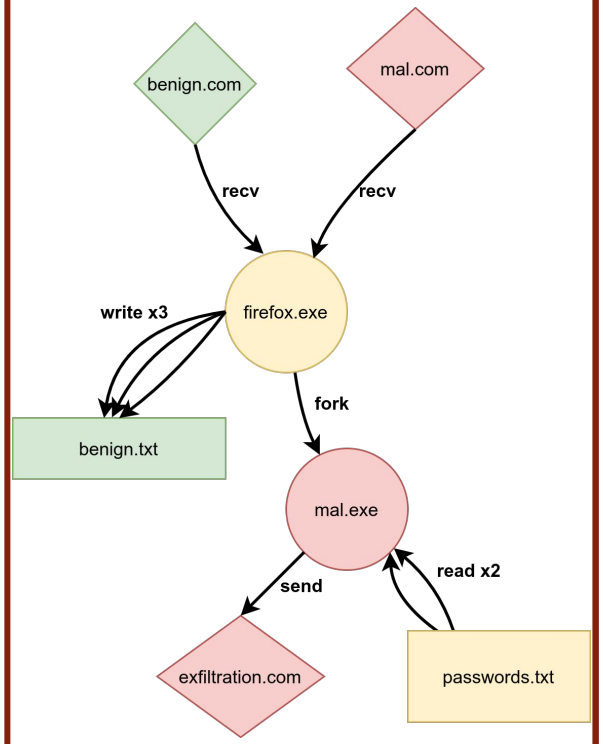

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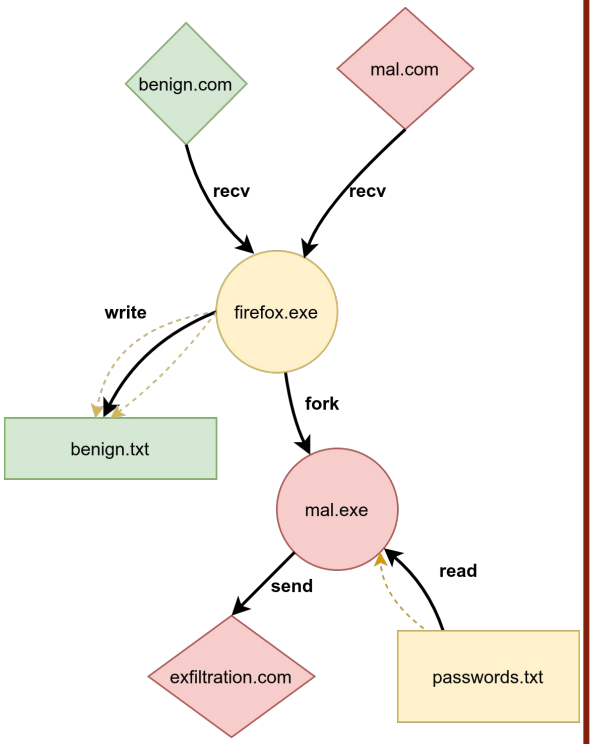

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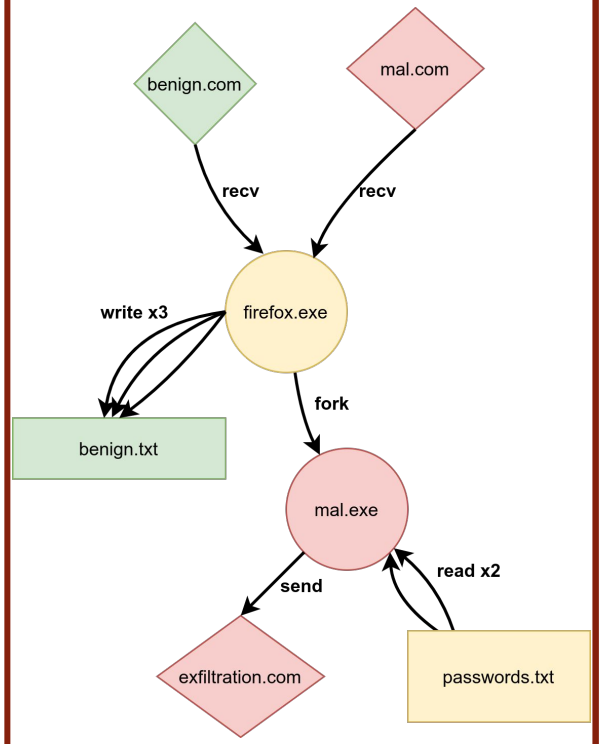

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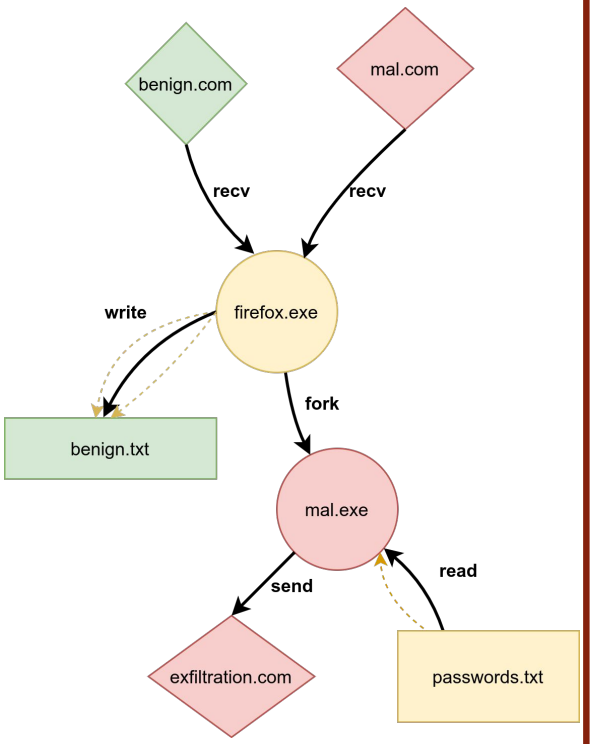

Attack-Preserving

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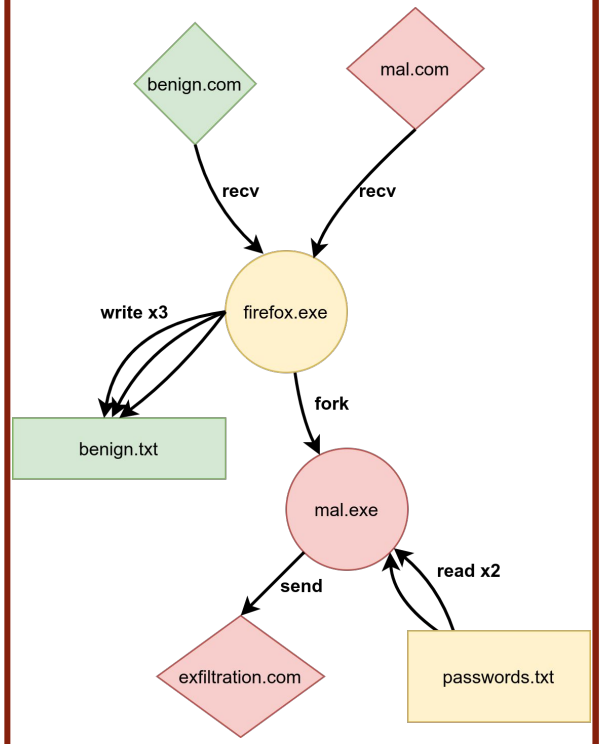

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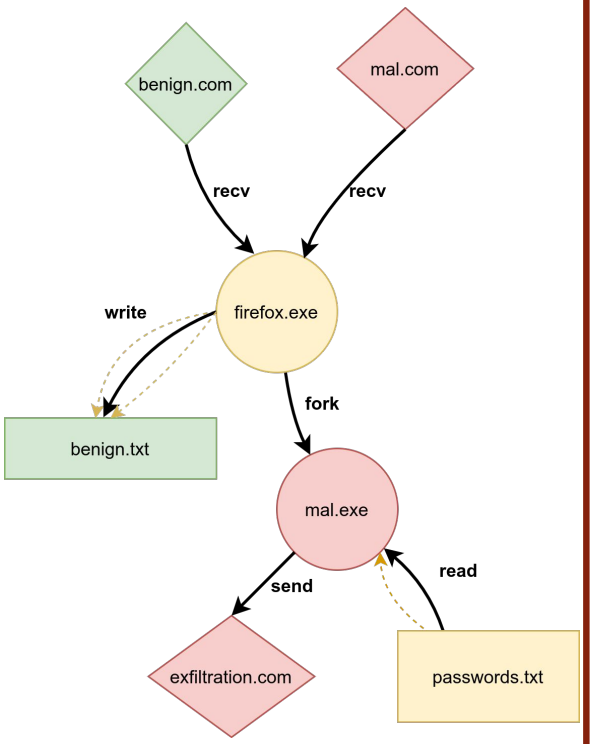

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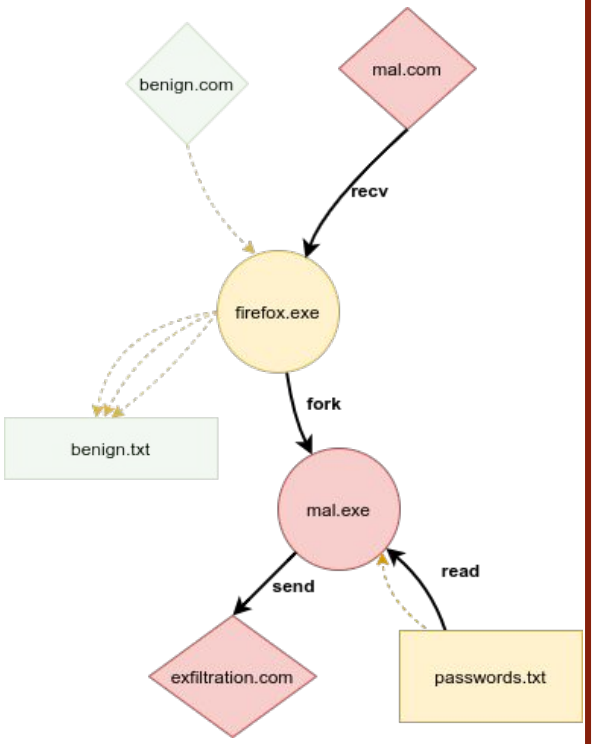

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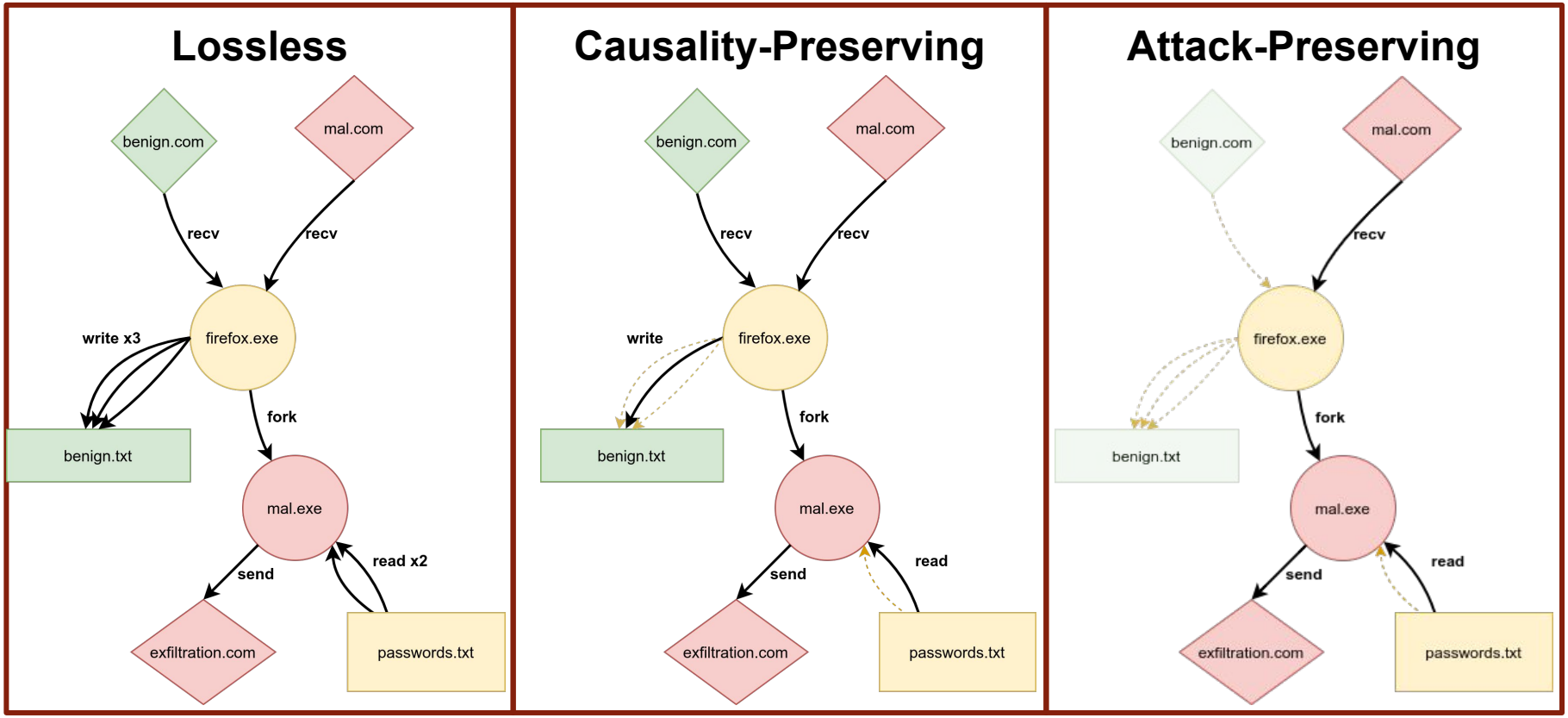

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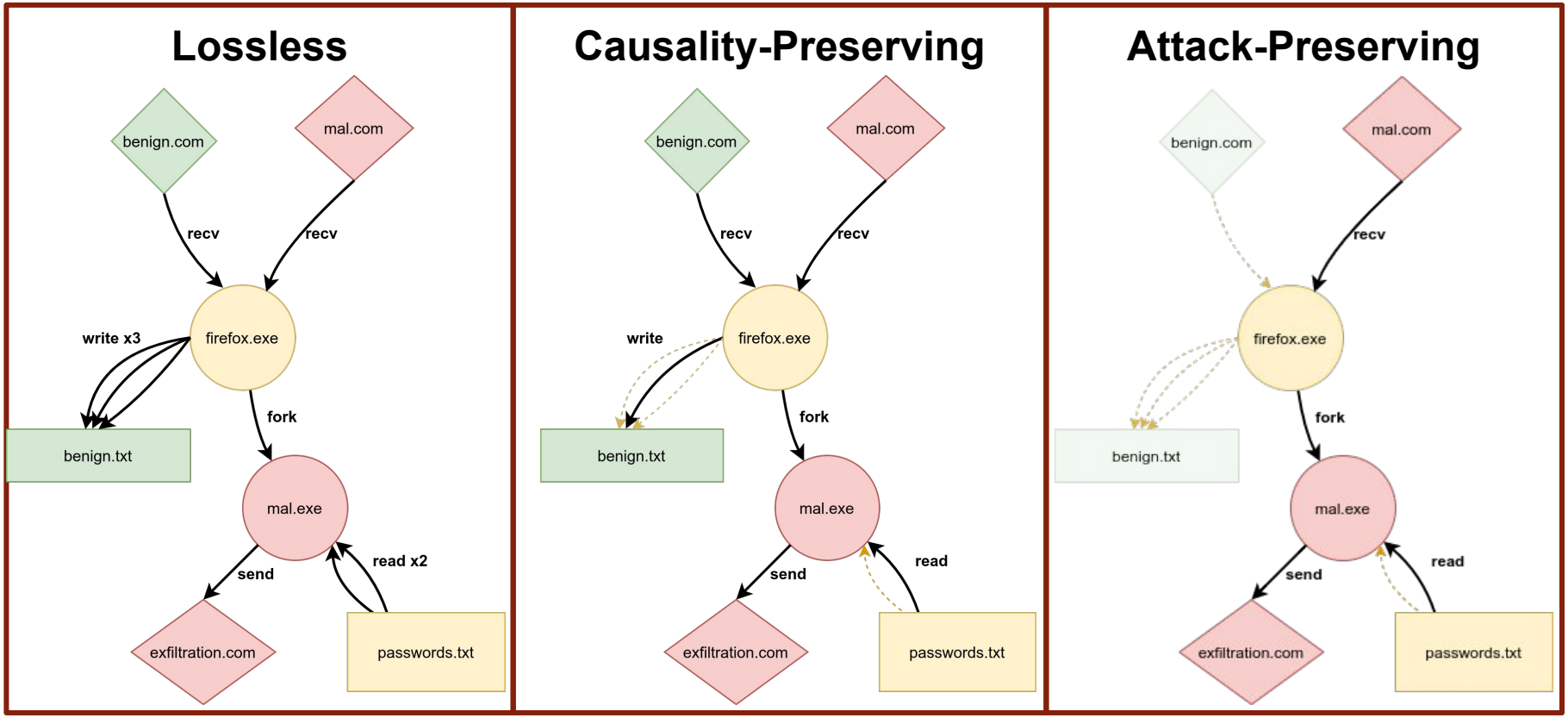

$$Reduction_i(G) = G_i$$

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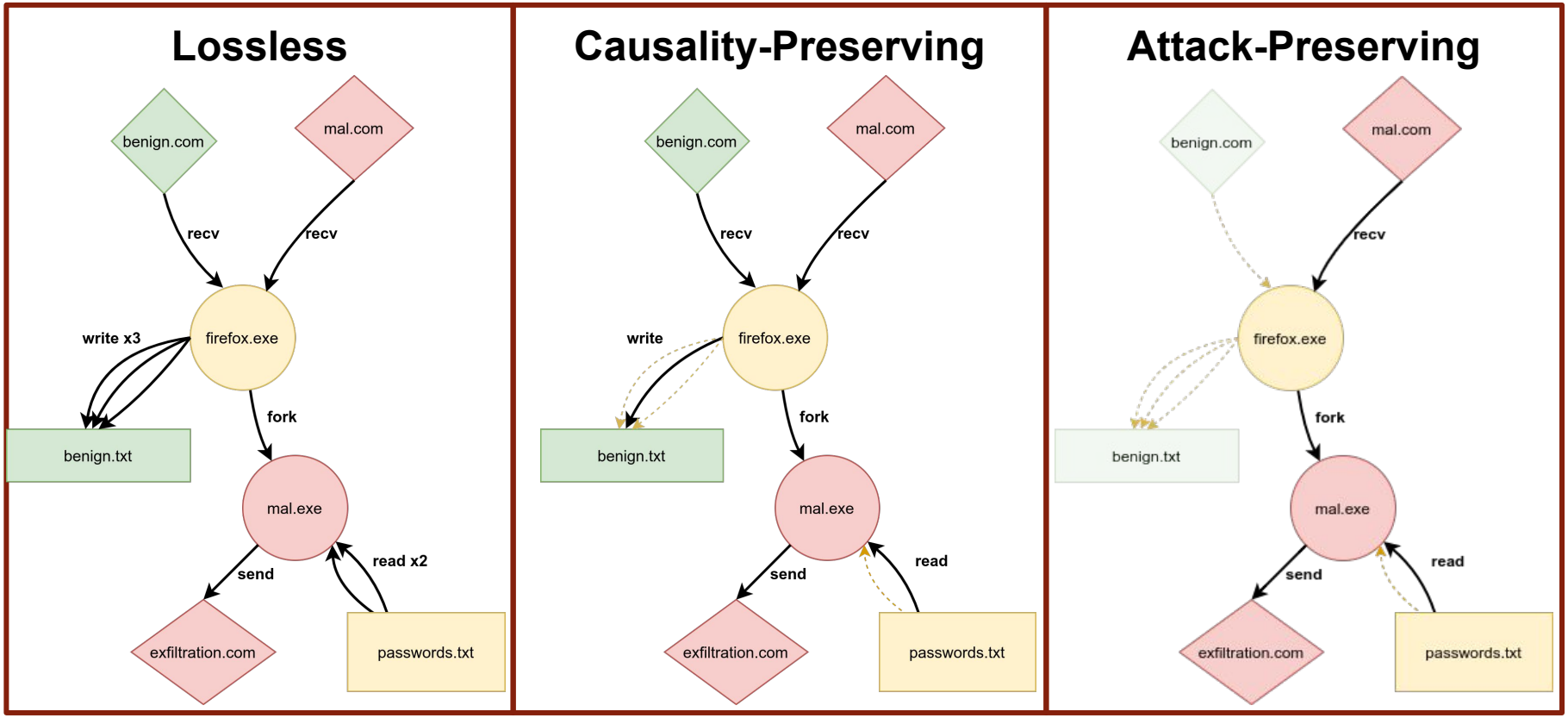

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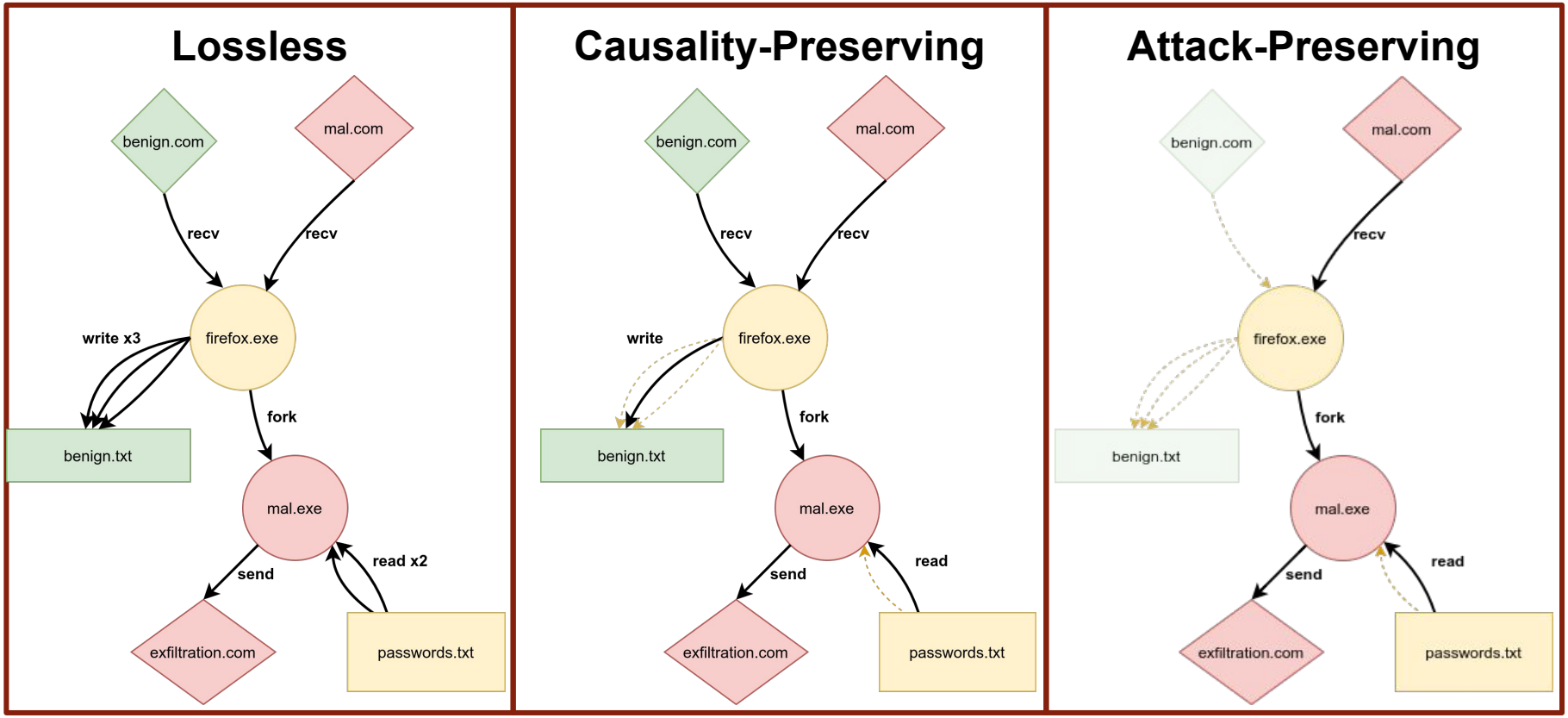

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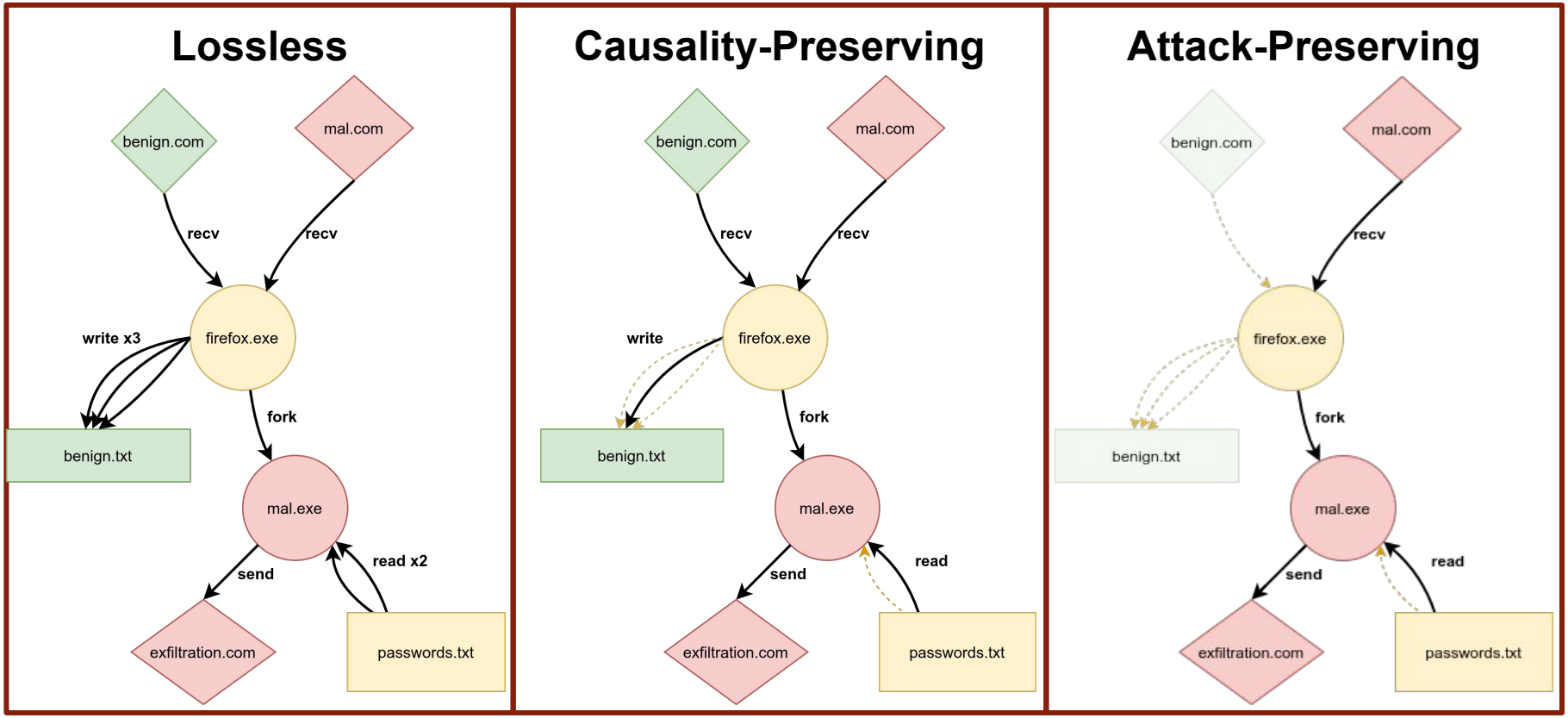

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$$\text{Forensic Validity}_{i,m} = \frac{|E(G_i) \cap E(G_m)|}{|E(G_m)|}$$

LogApprox

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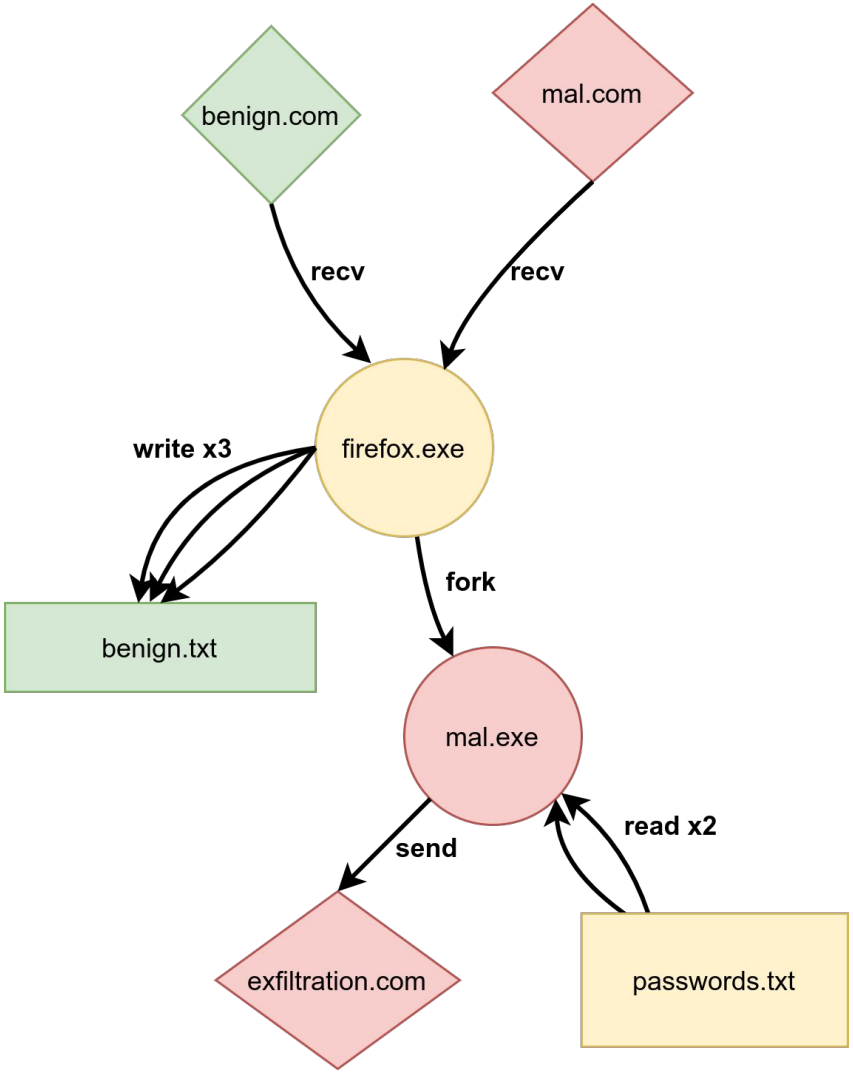
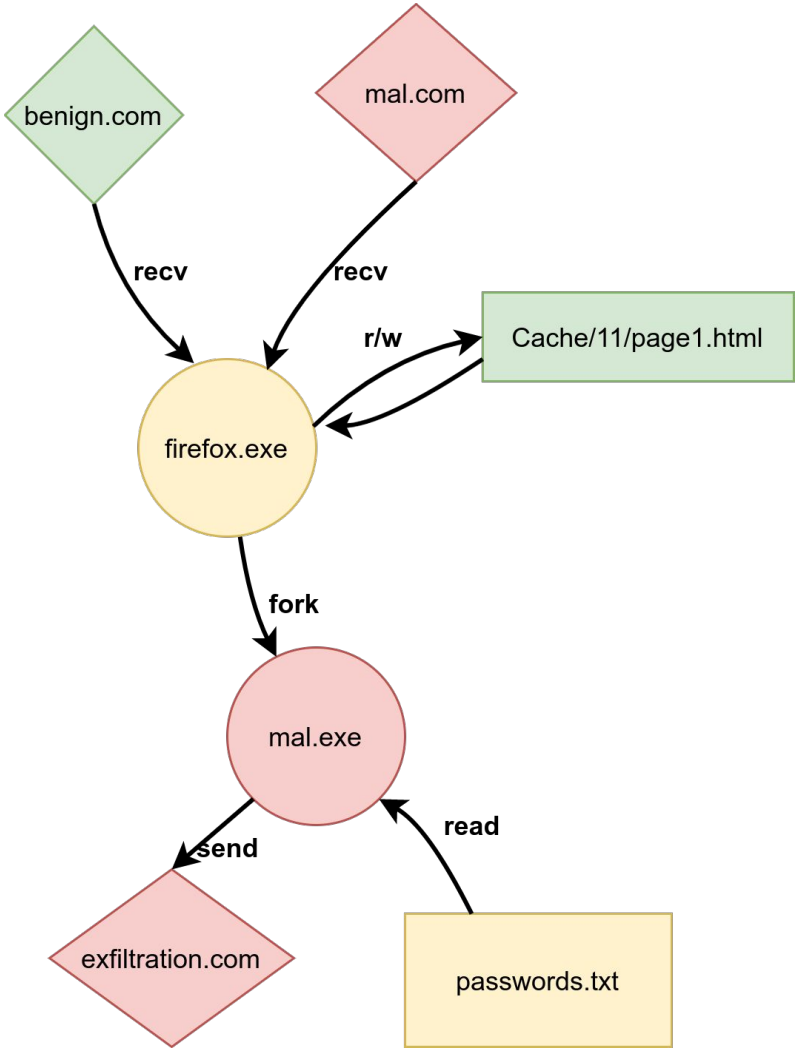

benign.com
mal.com
recv
recv
firefox.exe
write x3
benign.txt
fork
mal.exe
send
read x2
exfiltration.com
passwords.txt

LogApprox


benign.com
mal.com
recv
recv
r/w
Cache/11/page1.html
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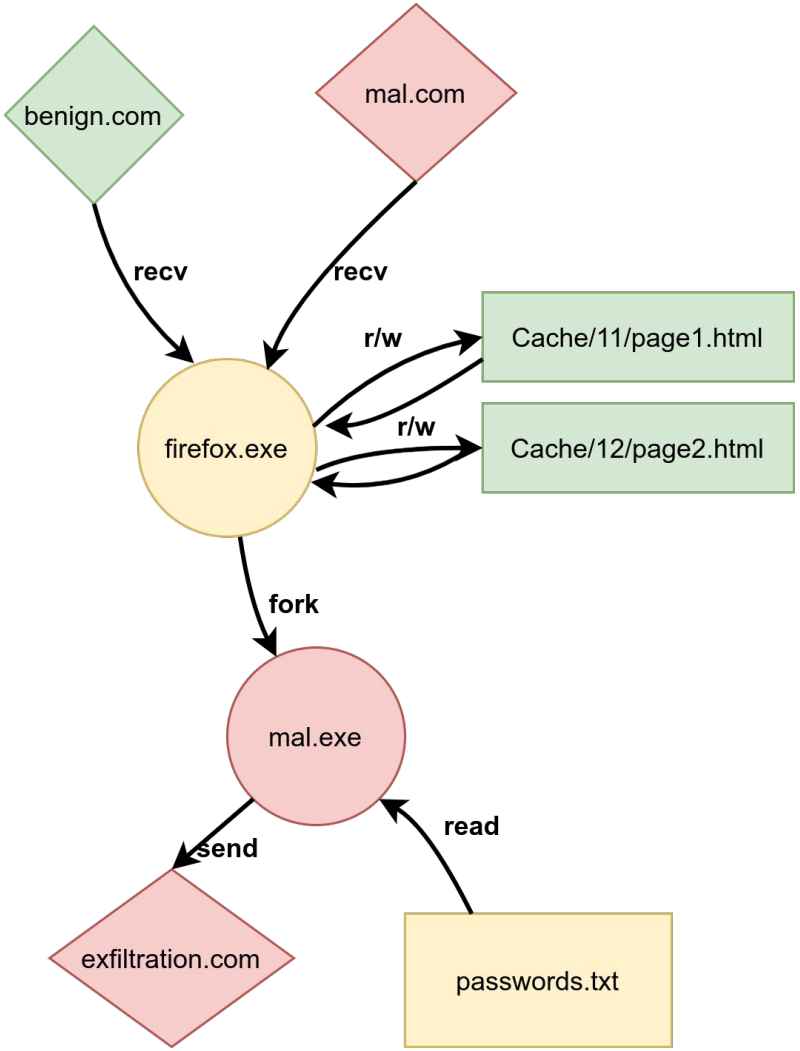
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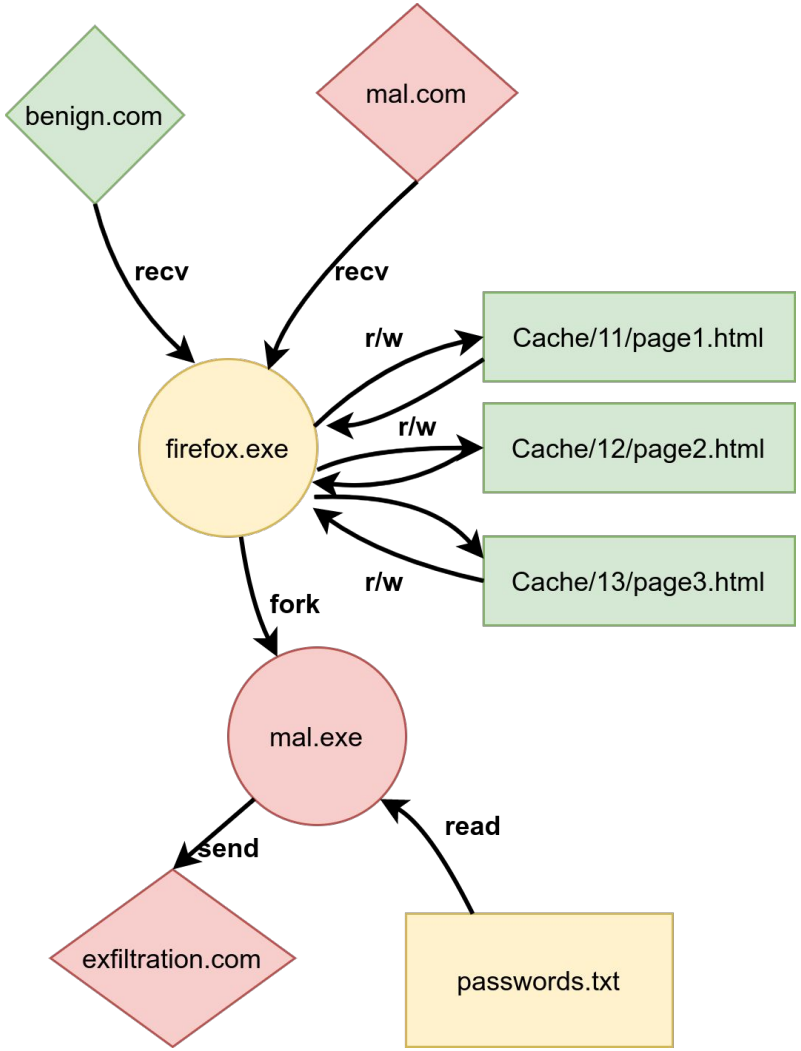
benign.com
mal.com
recv
recv
r/w
Cache/11/page1.html
firefox.exe
r/w
Cache/12/page2.html
r/w
Cache/13/page3.html
fork
mal.exe
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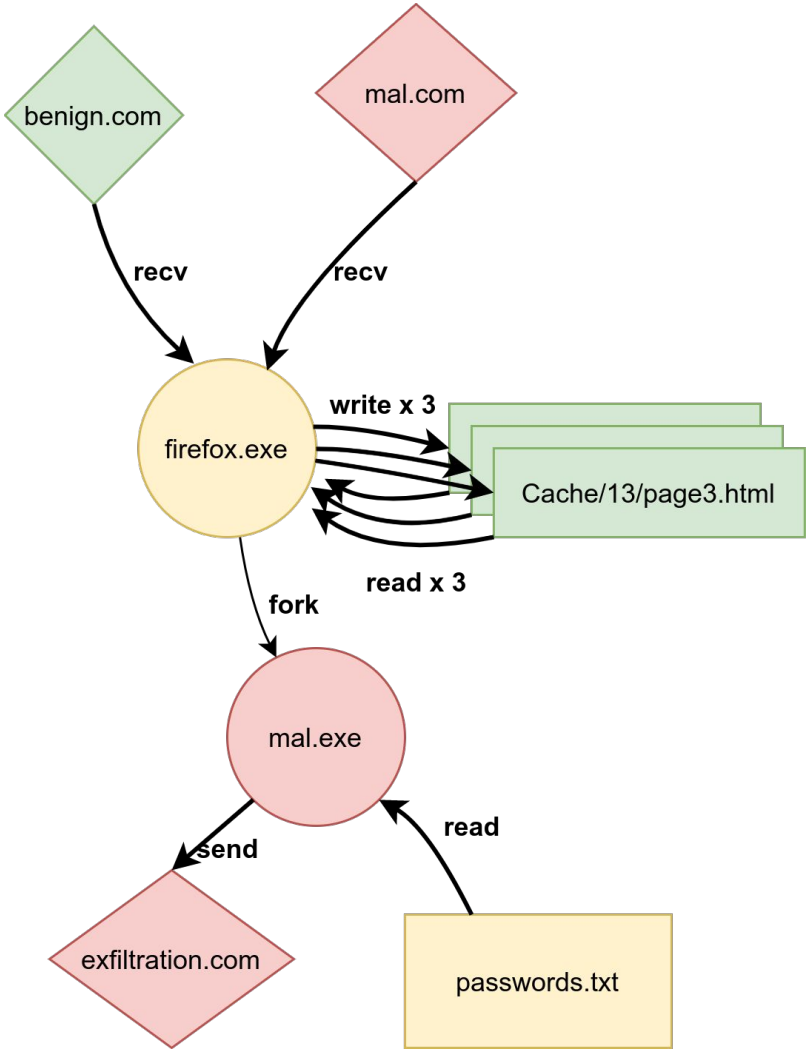
benign.com
mal.com
recv
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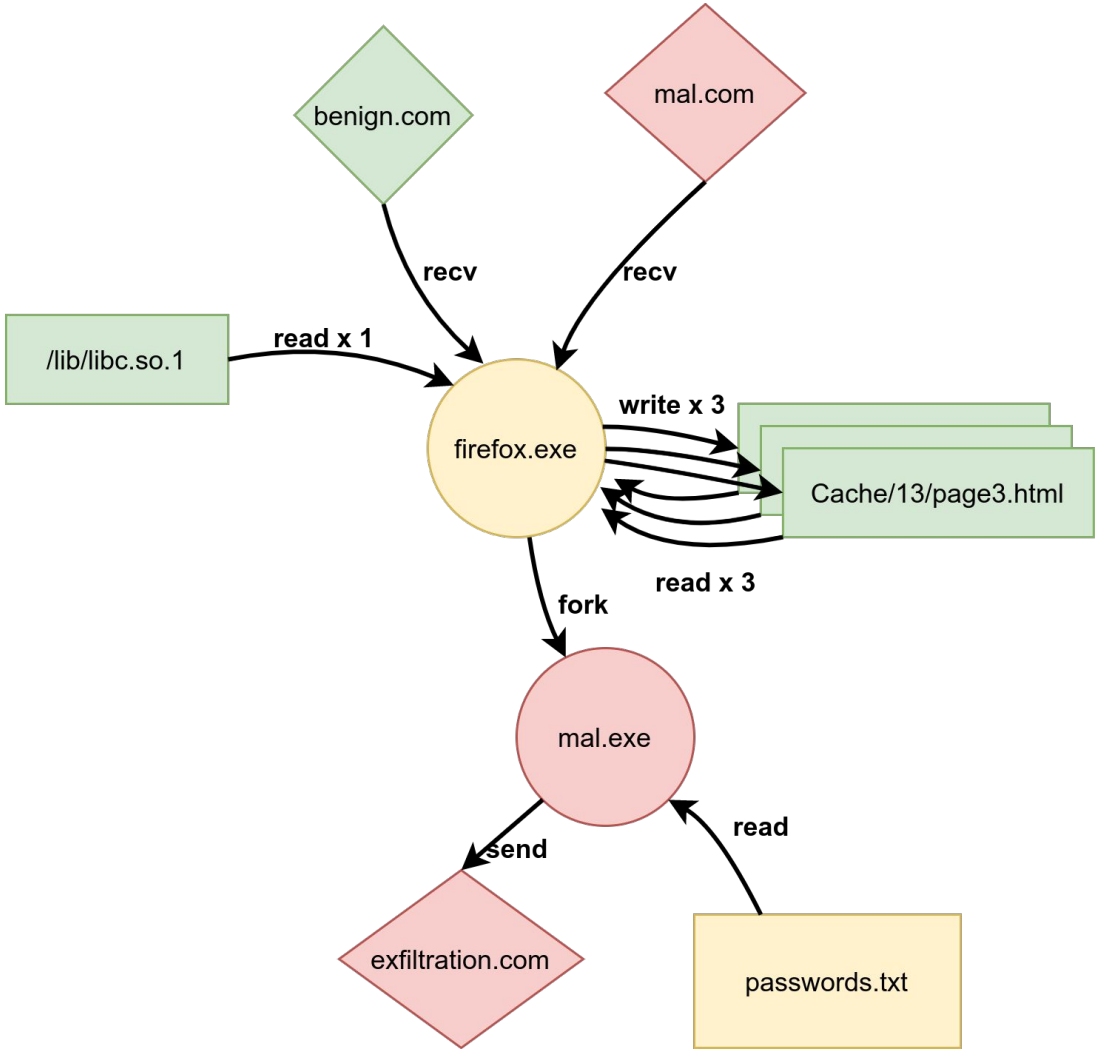
benign.com
mal.com
recv
recv
/lib/libc.so.1
read x 1
firefox.exe
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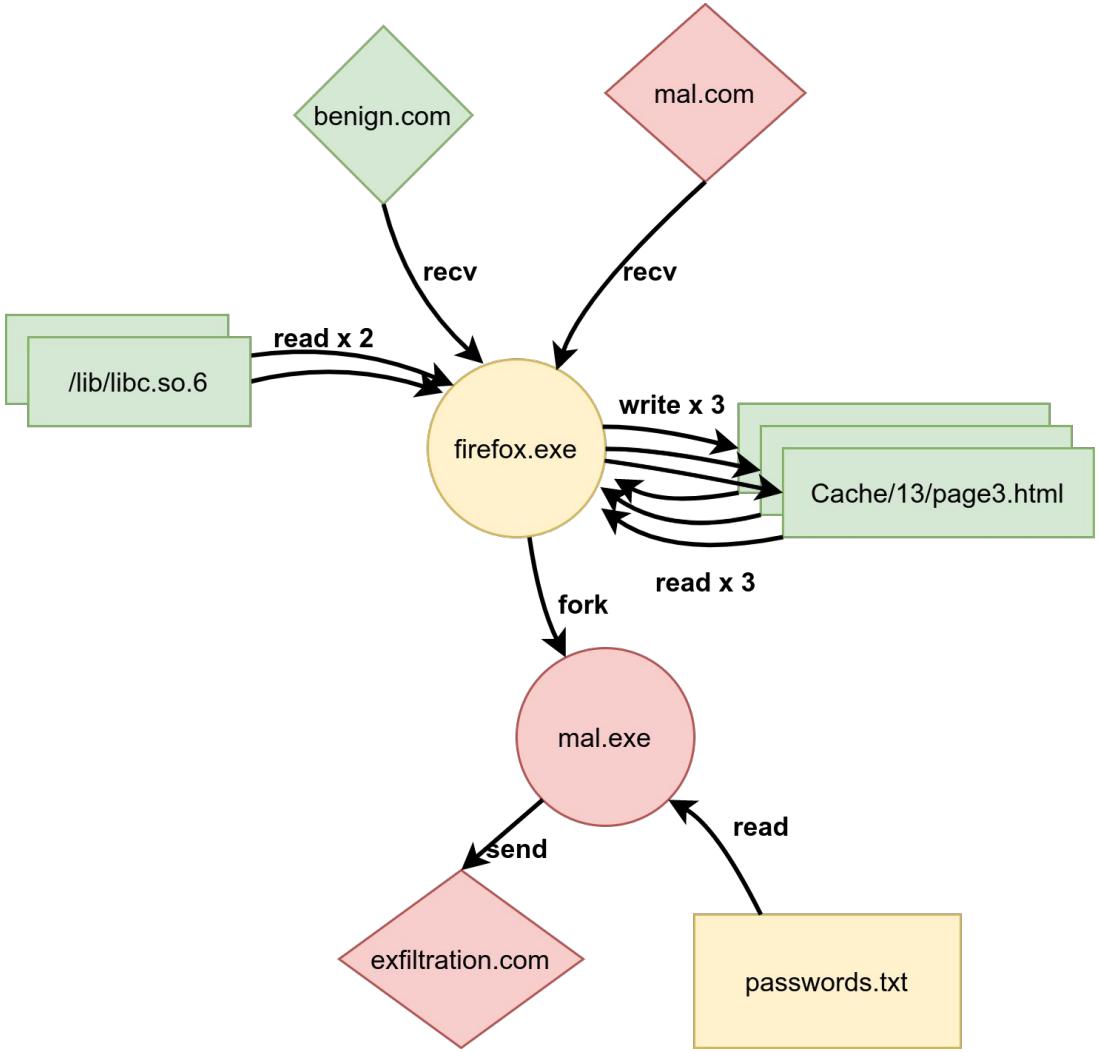
benign.com
mal.com
recv
recv
read x 2
/lib/libc.so.6
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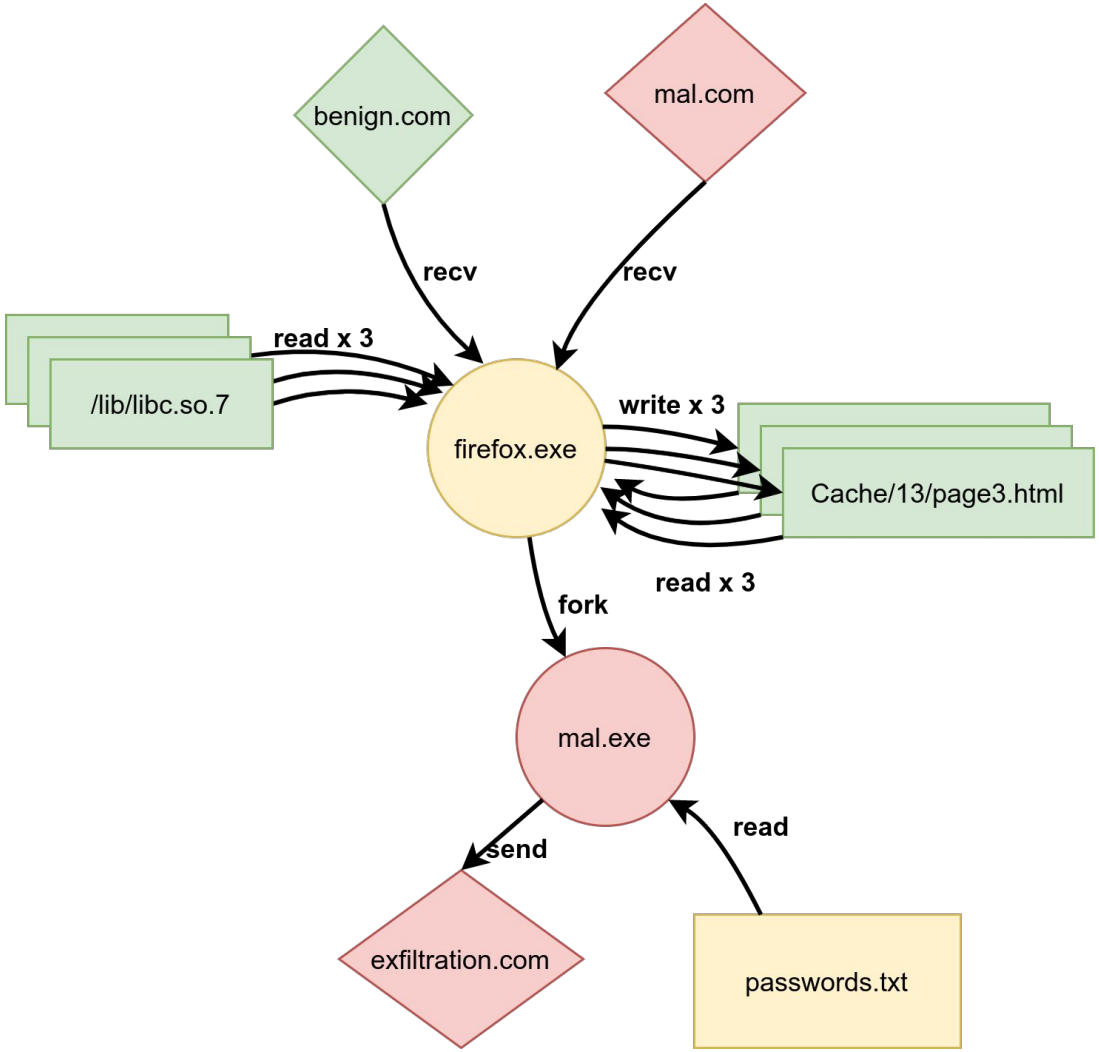
benign.com
mal.com
recv
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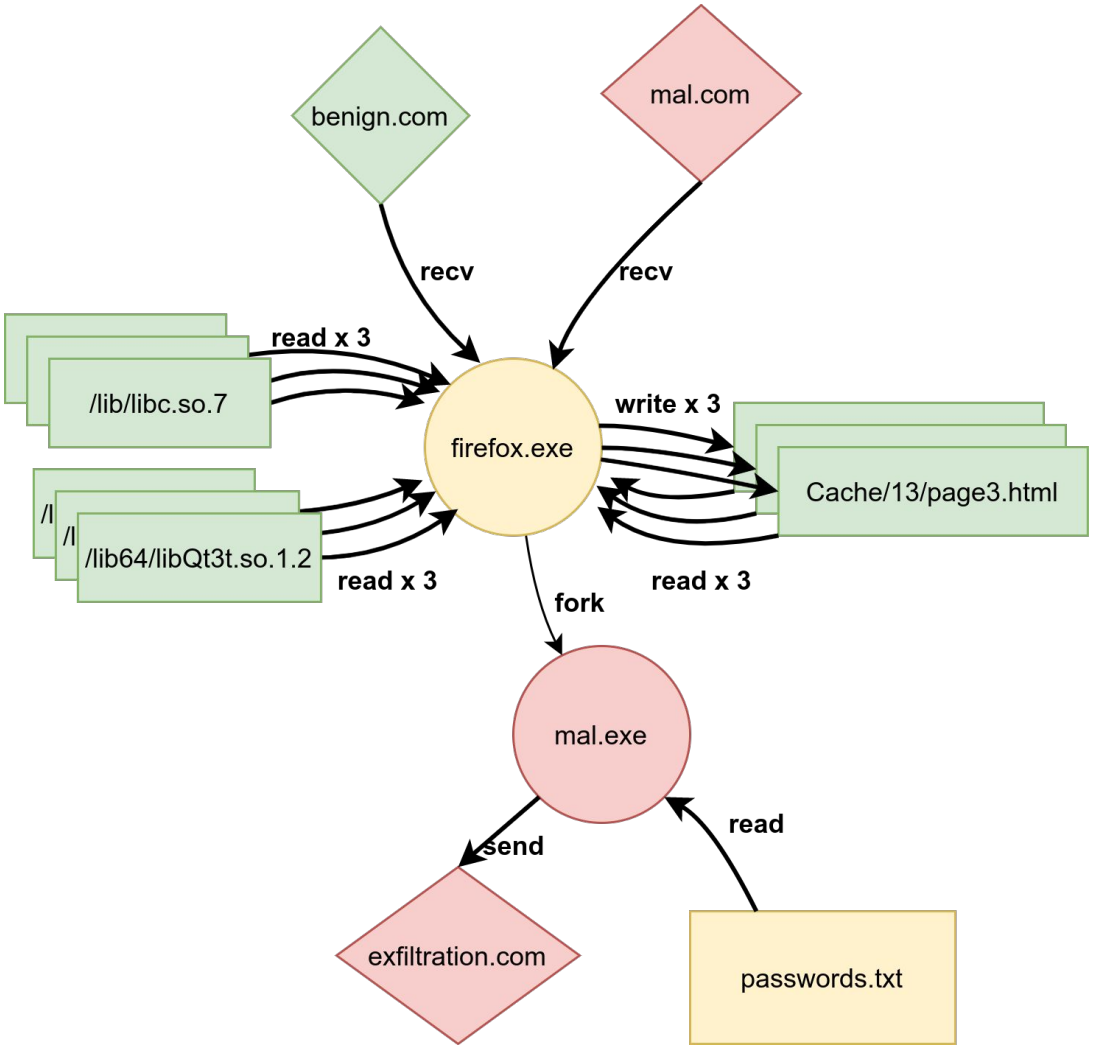
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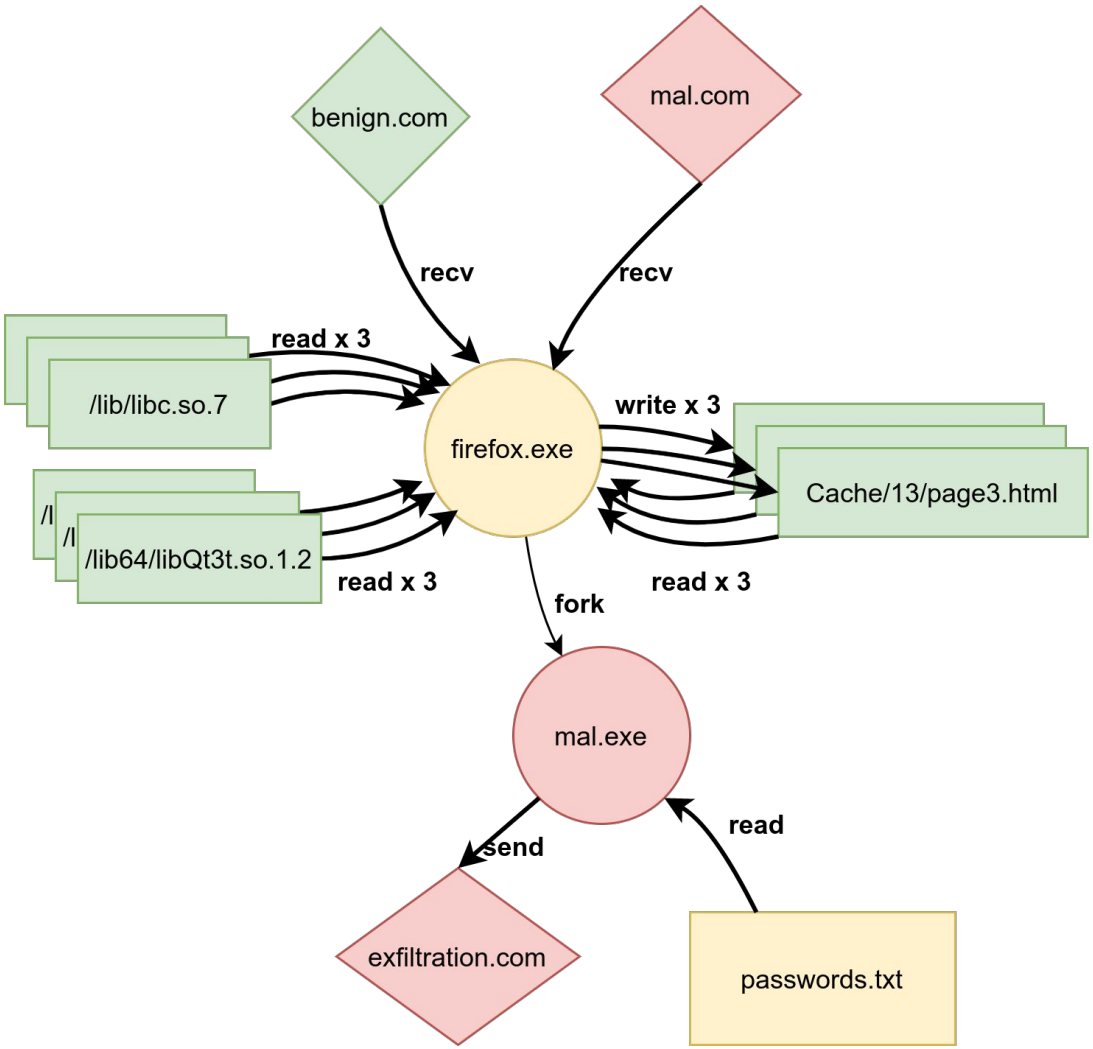
Reduction Opportunities

- Most system events are file IO events!
  - Related files unable to be causally reduced



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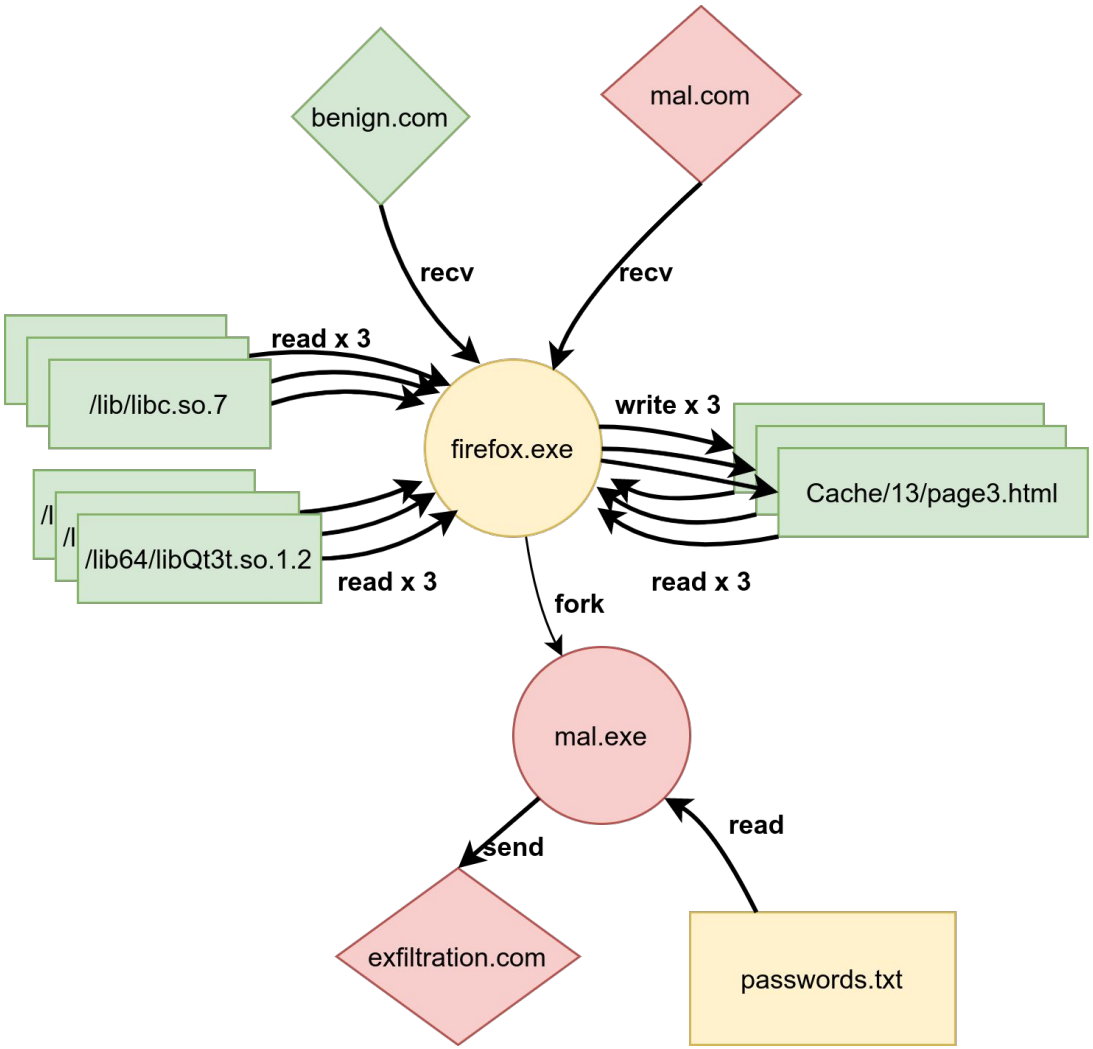
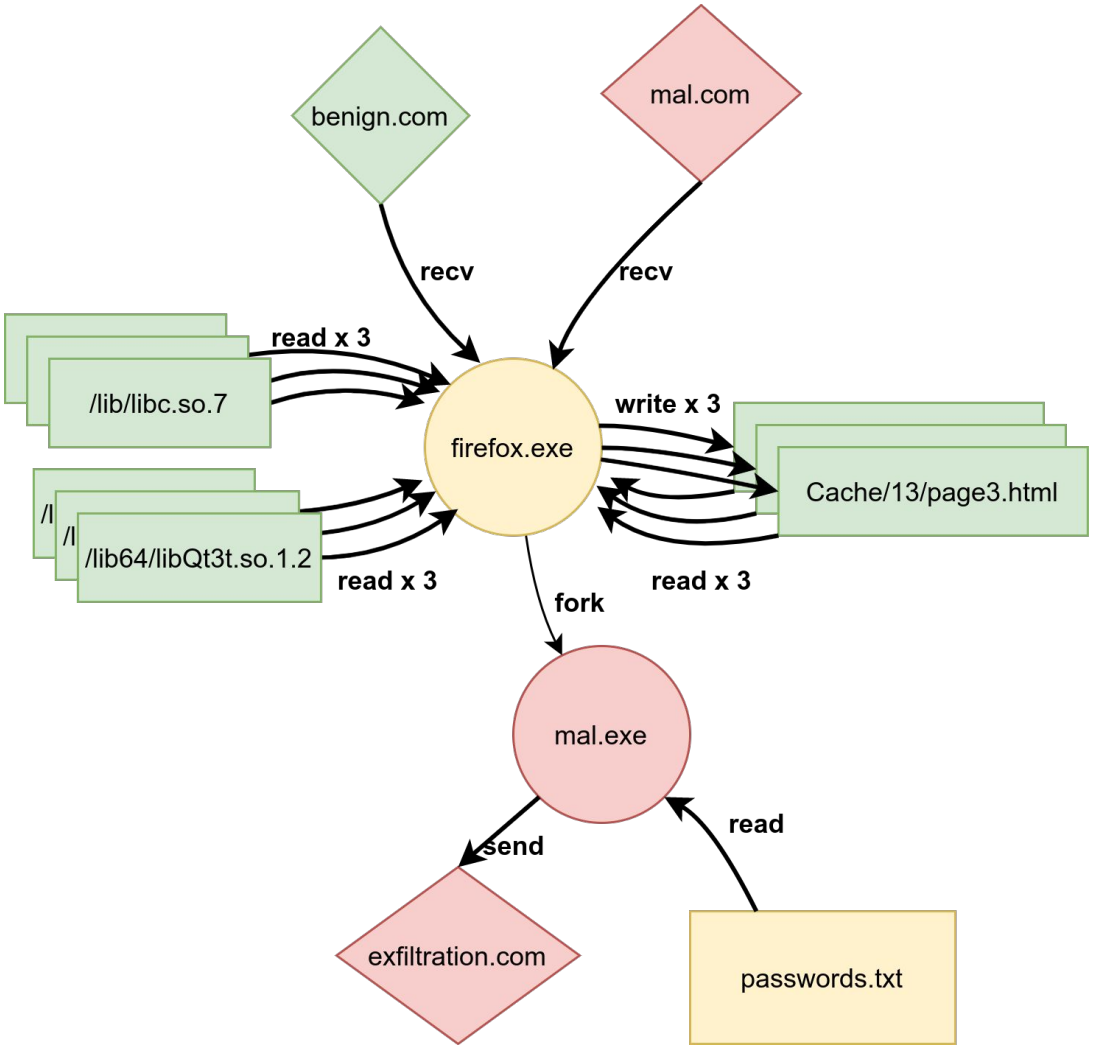
LogApprox Reduction:

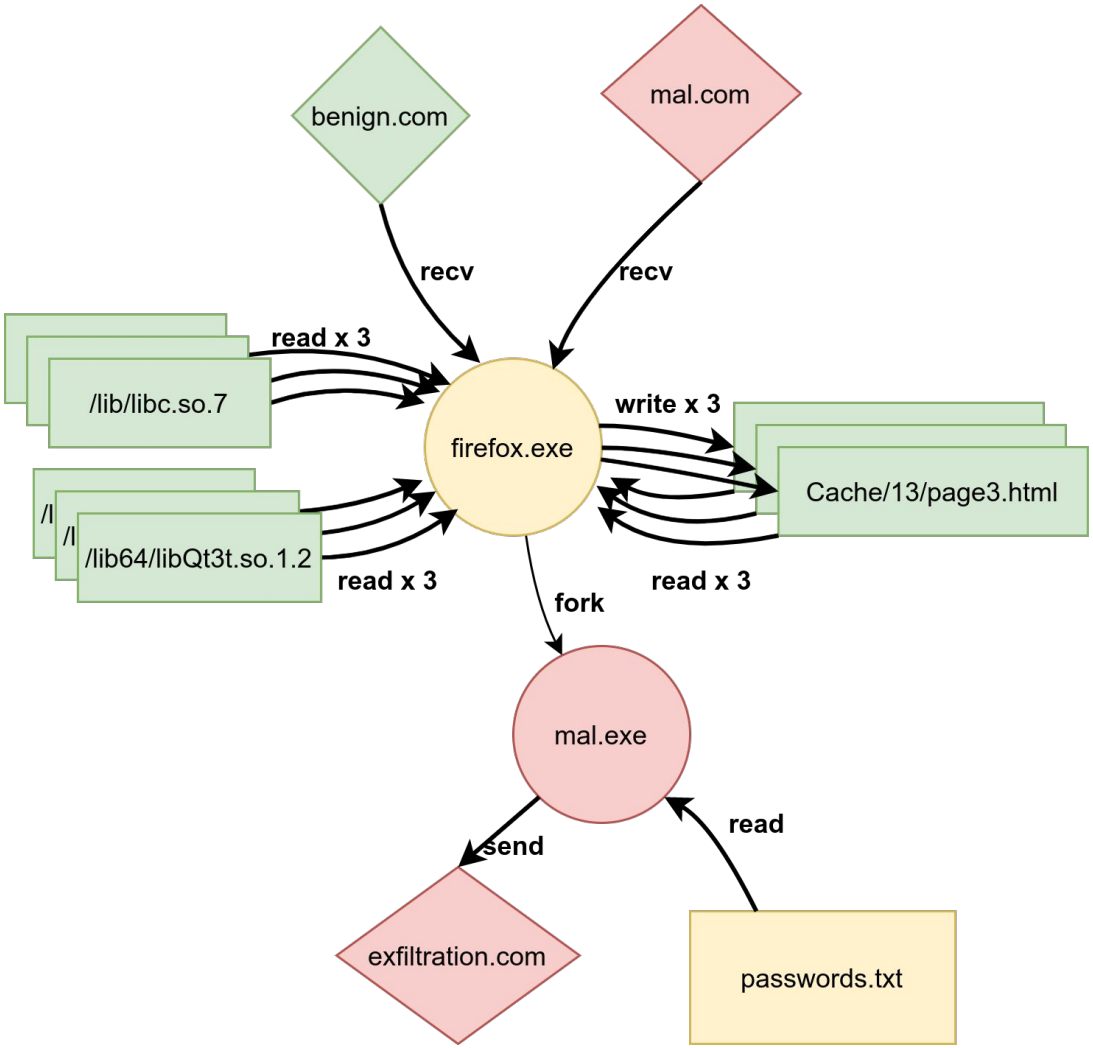
- Coalesce repetitive IO activity via <u>regexes</u>



LogApprox


benign.com
mal.com
recv
recv
read x 3
/lib/libc.so.7
firefox.exe
write x 3
Cache/13/page3.html
/lib64/libQt3t.so.1.2
read x 3
read x 3
fork
mal.exe
send
read
exfiltration.com
passwords.txt

LogApprox

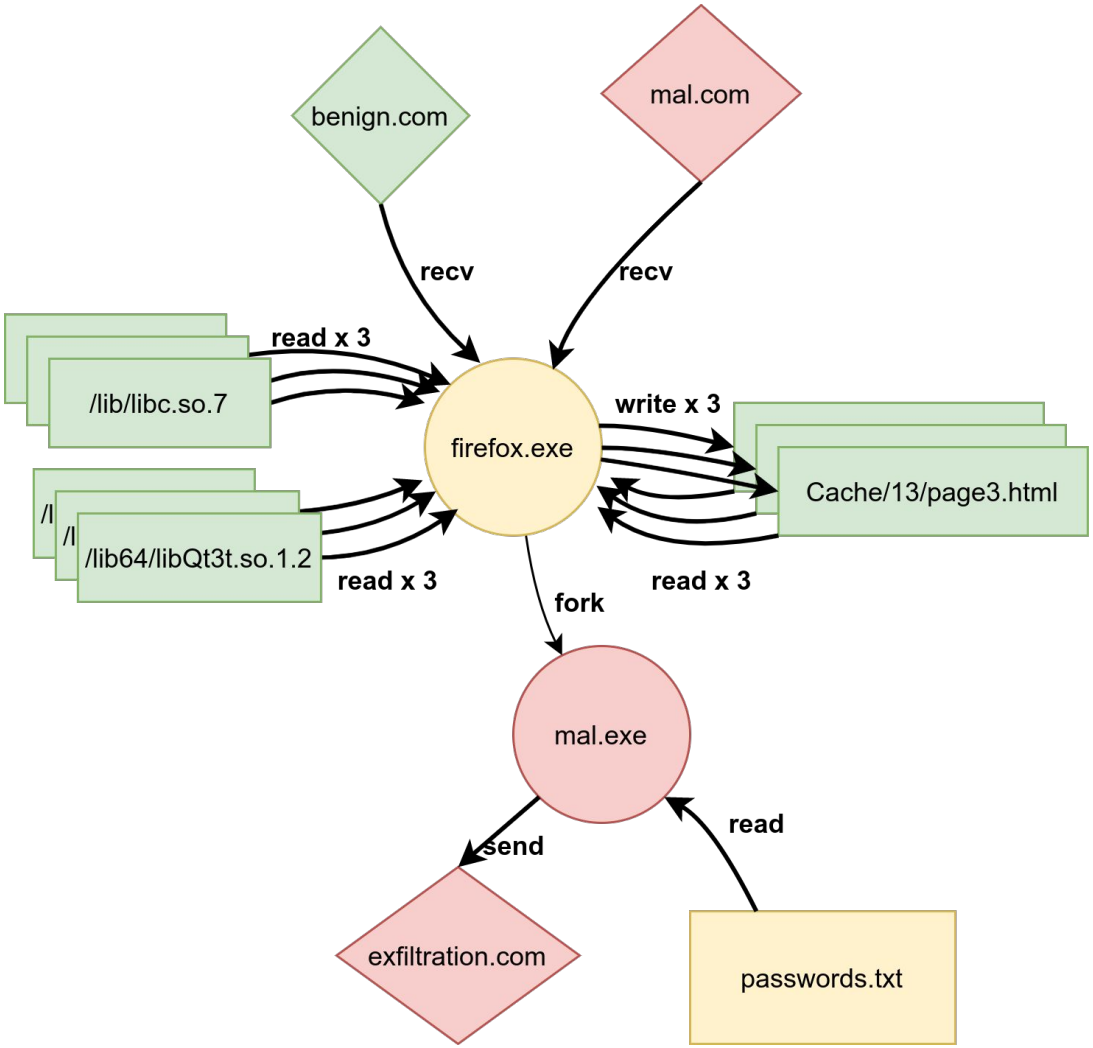


Filepaths for Firefox.exe

/Cache/11/page1.html
/Cache/12/page2.html
/Cache/13/page3.html
/lib/libc.so.1
/lib/libc.so.6
/lib/libc.so.7
/lib64/libQt3t.so.1
/lib64/libQt3t.so.1.1
/lib64/libQt3t.so.1.2

LogApprox

Group 1:
/Cache/11/page1.html



Filepaths for Firefox.exe

/Cache/12/page2.html
/Cache/13/page3.html
/lib/libc.so.1
/lib/libc.so.6
/lib/libc.so.7
/lib64/libQt3t.so.1
/lib64/libQt3t.so.1.1
/lib64/libQt3t.so.1.2

LogApprox

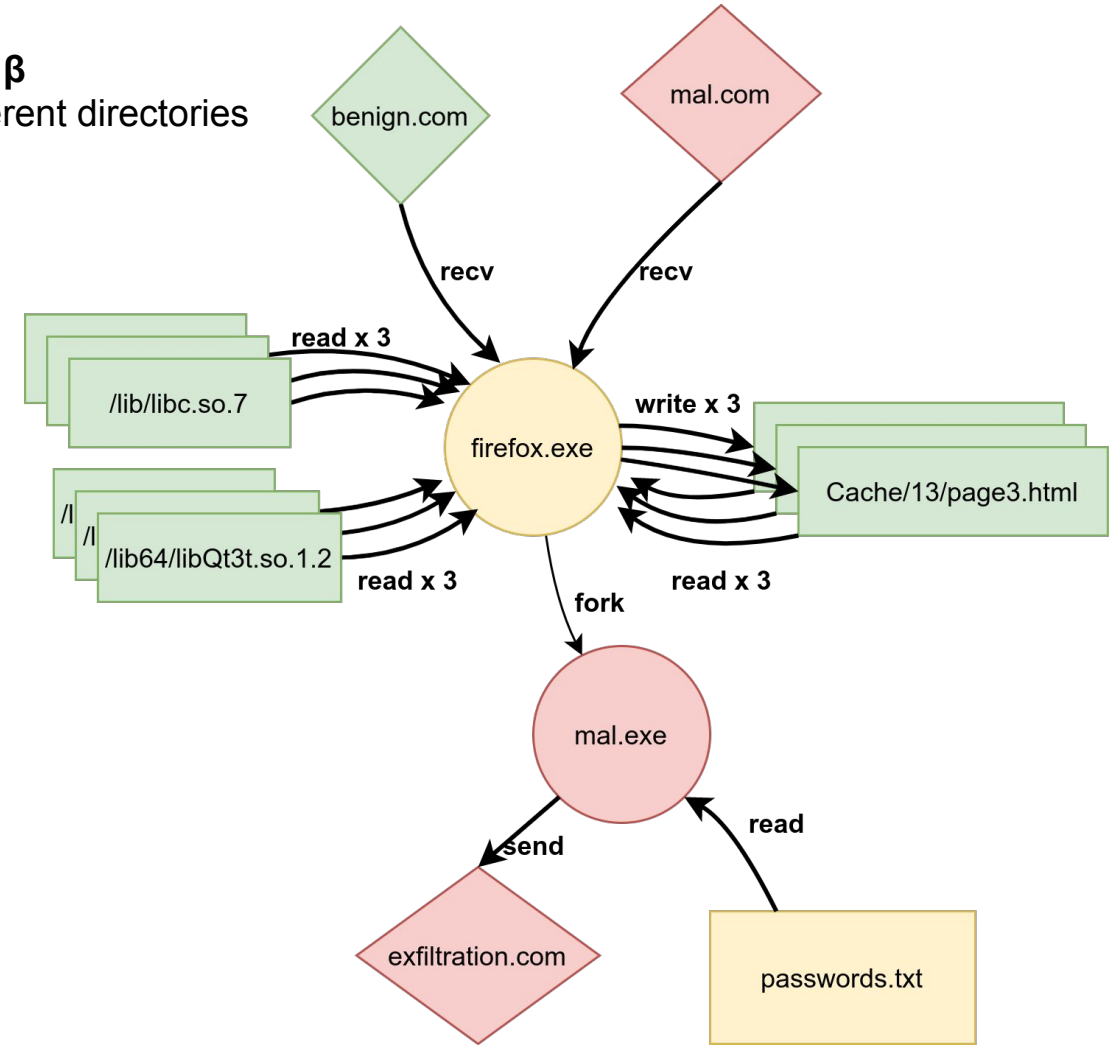
Group by:

Filename Similarity: **A**
Levenshtein Edit Distance

Path Distance: **β**
Number of different directories

Group 1:

/Cache/11/page1.html



Filepaths for Firefox.exe

/Cache/12/page2.html
/Cache/13/page3.html
/lib/libc.so.1
/lib/libc.so.6
/lib/libc.so.7
/lib64/libQt3t.so.1
/lib64/libQt3t.so.1.1
/lib64/libQt3t.so.1.2

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Number of different directories

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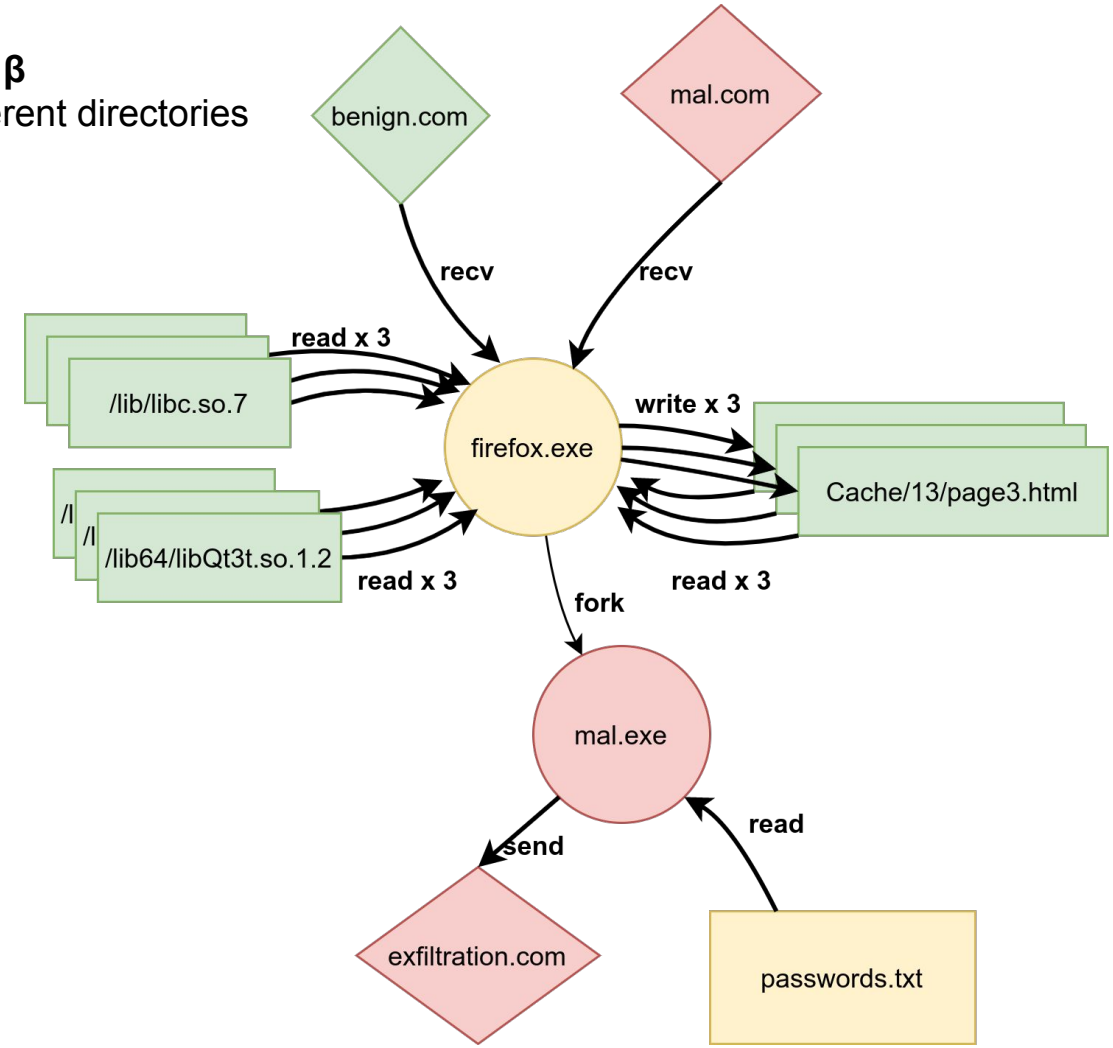
/Cache/11/page1.html
/Cache/12/page2.html
/Cache/13/page3.html



Filepaths for Firefox.exe

/lib/libc.so.1
/lib/libc.so.6
/lib/libc.so.7
/lib64/libQt3t.so.1
/lib64/libQt3t.so.1.1
/lib64/libQt3t.so.1.2

LogApprox

Group by:

Filename Similarity: **A**
Levenshtein Edit Distance

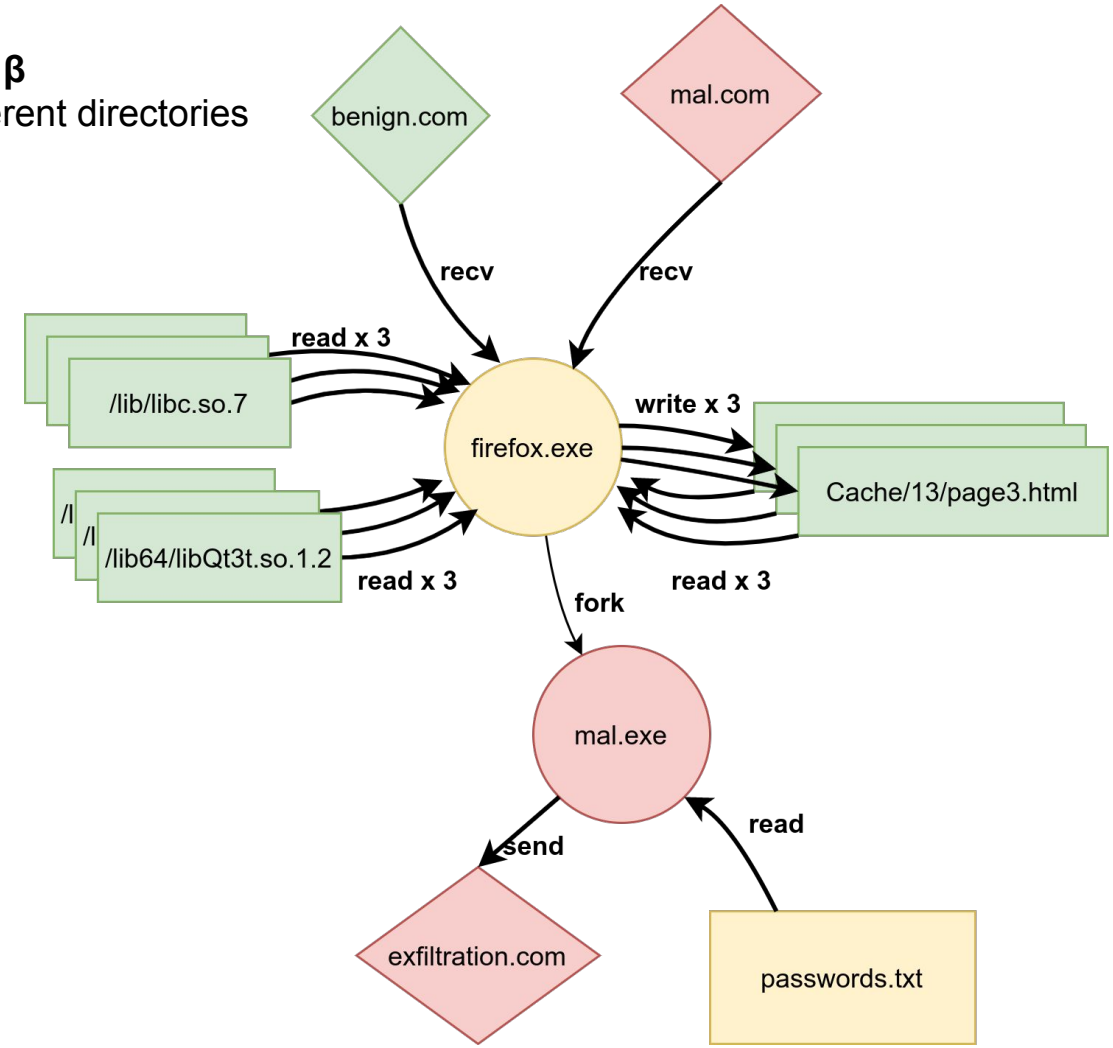
Path Distance: **β**
Number of different directories

Group 1:

/Cache/11/page1.html
/Cache/12/page2.html
/Cache/13/page3.html

Group 2:

/lib/libc.so.1



Filepaths for Firefox.exe

/lib/libc.so.6
/lib/libc.so.7
/lib64/libQt3t.so.1
/lib64/libQt3t.so.1.1
/lib64/libQt3t.so.1.2

LogApprox

Group by:

Filename Similarity: **A**
Levenshtein Edit Distance

Path Distance: **β**
Number of different directories

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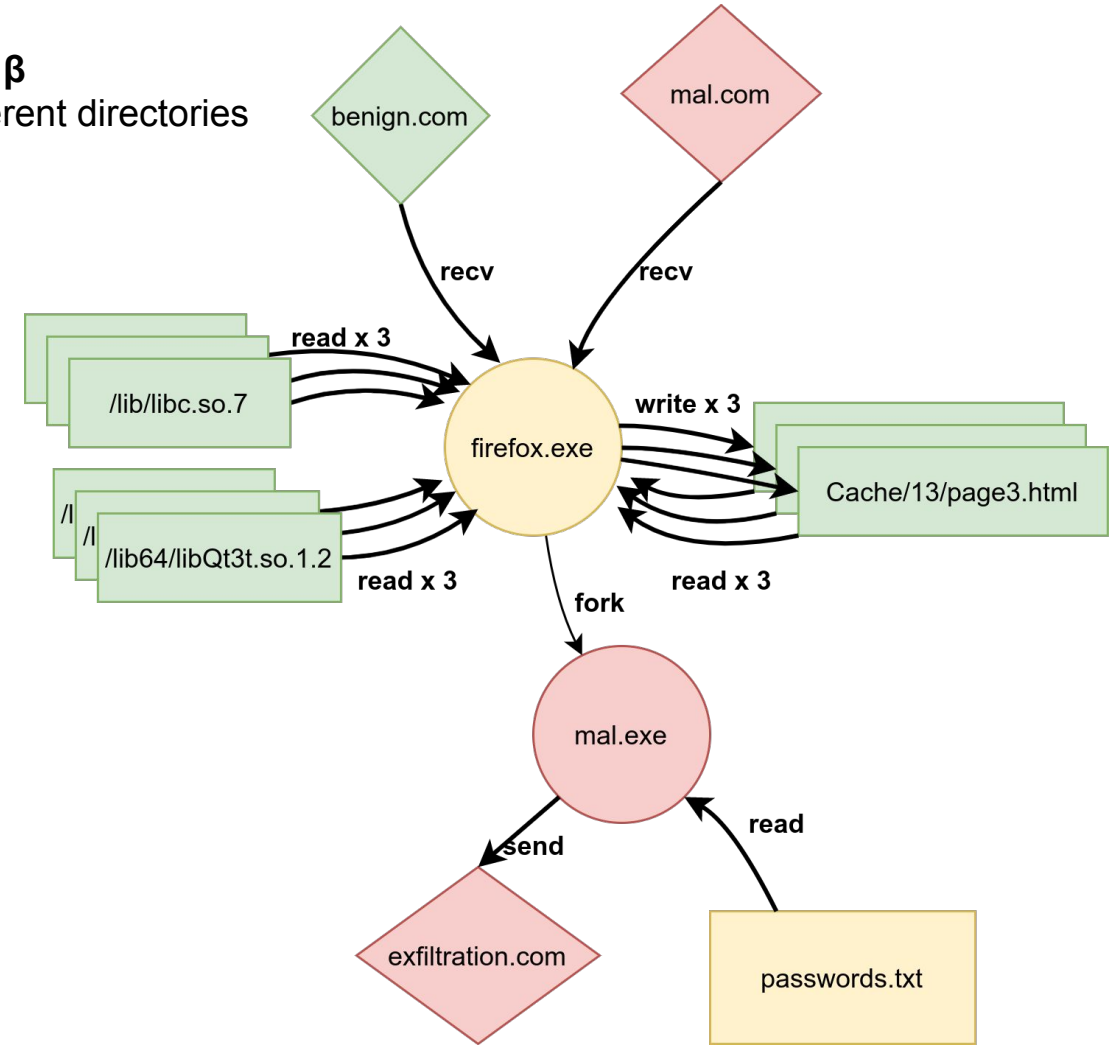
/Cache/11/page1.html
/Cache/12/page2.html
/Cache/13/page3.html

Group 2:
/lib/libc.so.1
/lib/libc.so.6
/lib/libc.so.7

Group 3:
/lib64/libQt3t.so.1
/lib64/libQt3t.so.1.1
/lib64/libQt3t.so.1.2



LogApprox

Group by:

Filename Similarity: **A**
Levenshtein Edit Distance

Path Distance: **β**
Number of different directories

Group 1:

/Cache/11/page1.html
/Cache/12/page2.html
/Cache/13/page3.html

/Cache/*/page*

Group 2:

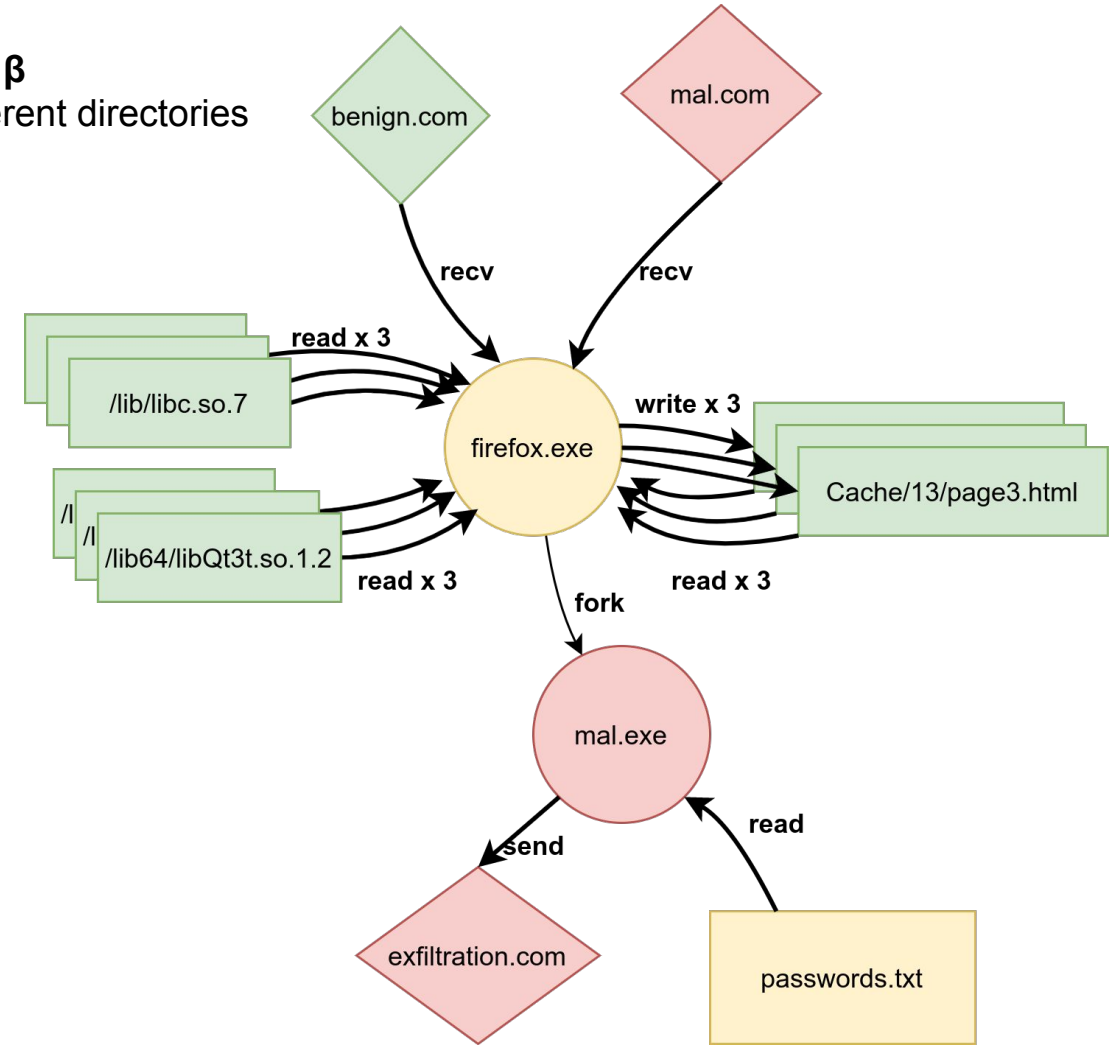
/lib/libc.so.1
/lib/libc.so.6
/lib/libc.so.7

/lib/libc.so.*

Group 3:

/lib64/libQt3t.so.1
/lib64/libQt3t.so.1.1
/lib64/libQt3t.so.1.2

/lib64/libQt3t.so.1*



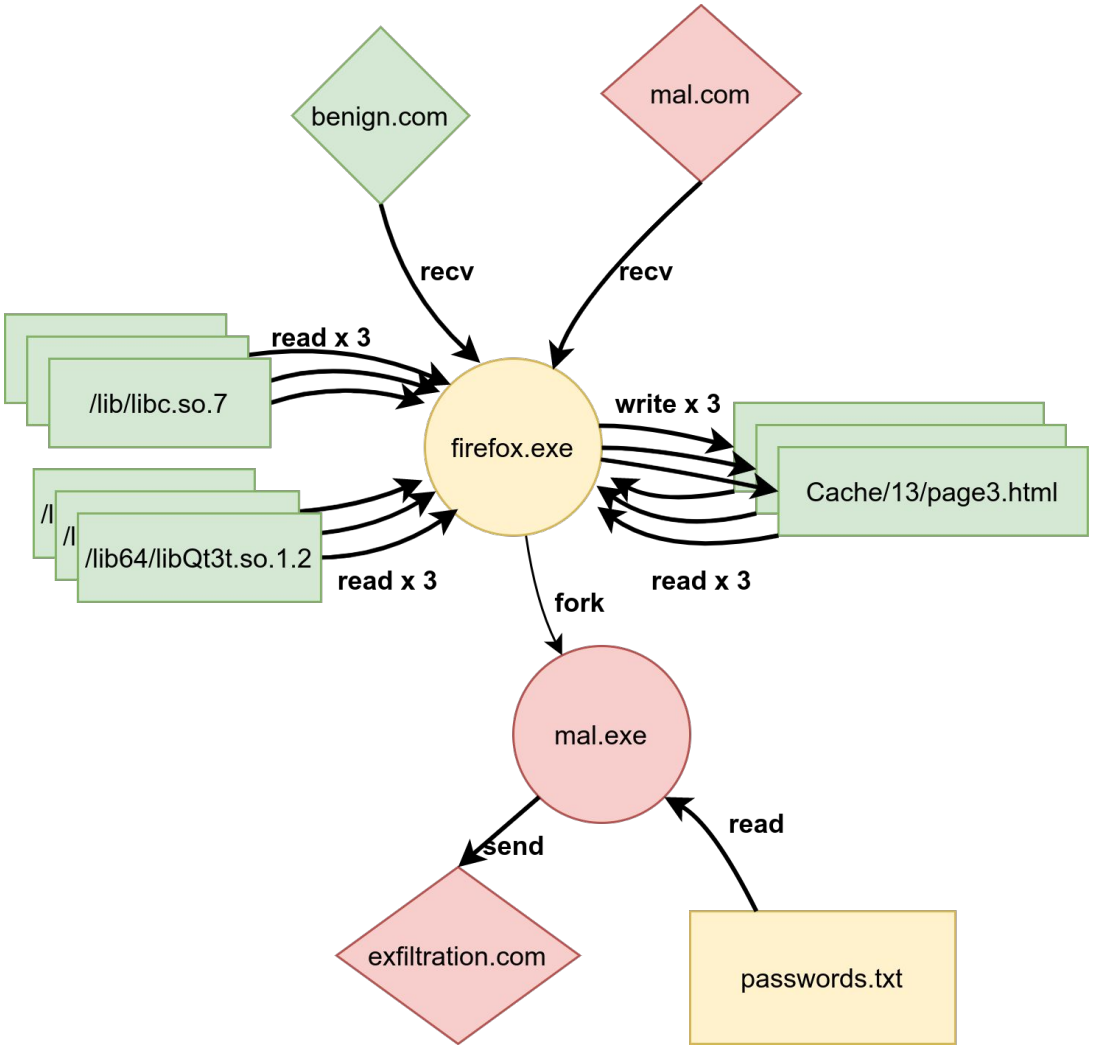
LogApprox

Firefox IO Templates:

/Cache/*/page*

/lib/libc.so.*

/lib64/libQt3t.so.1*



LogApprox

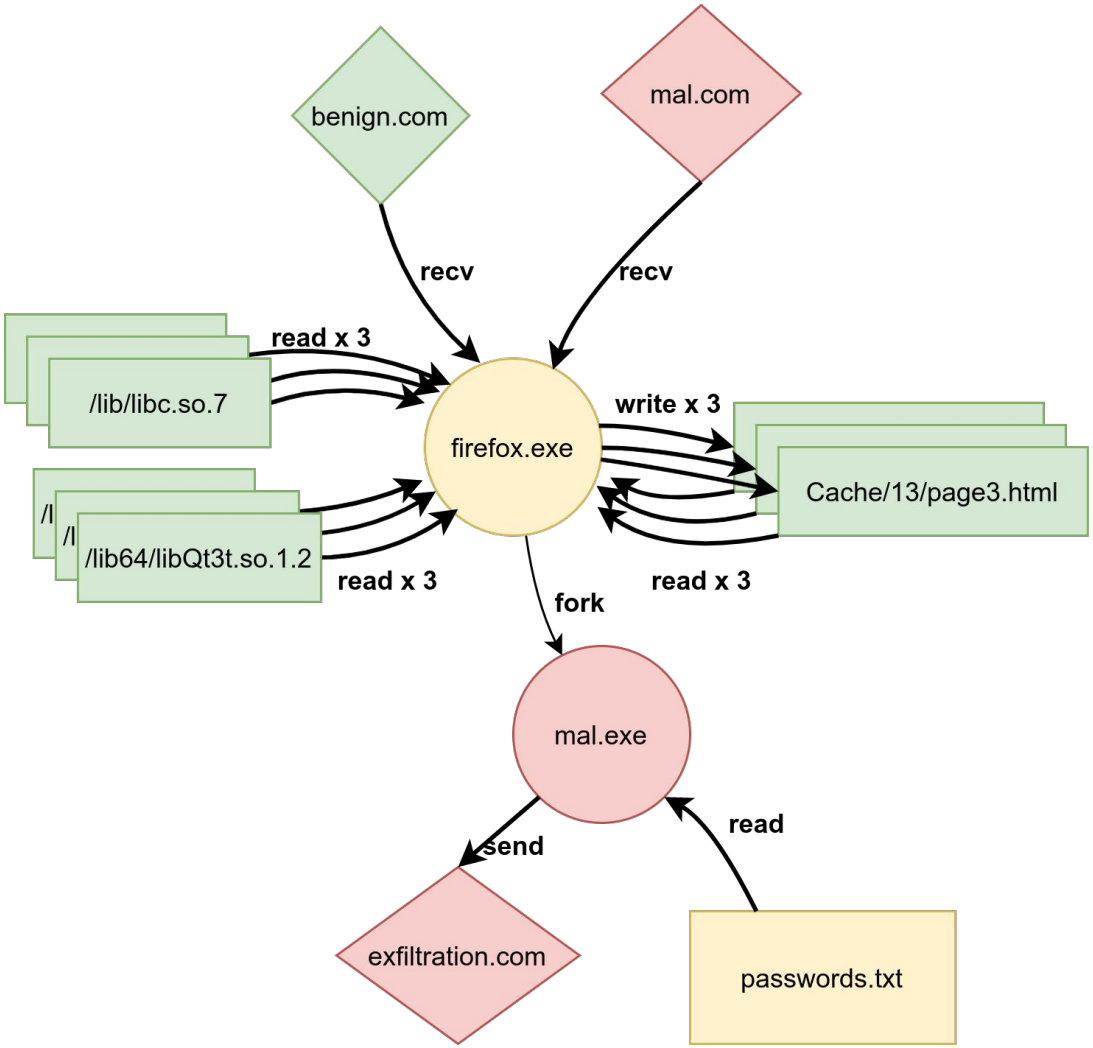
Firefox IO Templates:

/Cache/*/page*

/lib/libc.so.*

/lib64/libQt3t.so.1*

APPLY



LogApprox

Firefox IO Templates:

/Cache/*/page*

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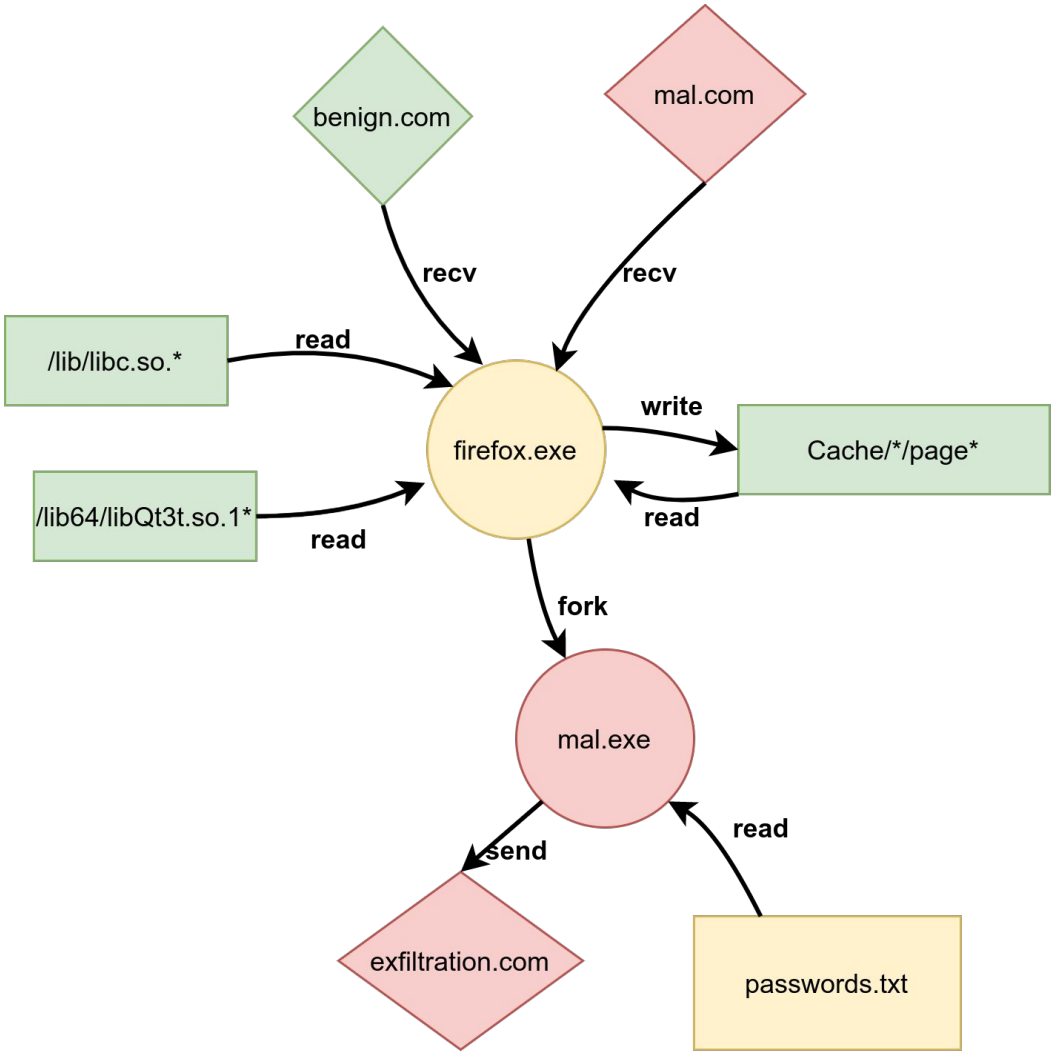
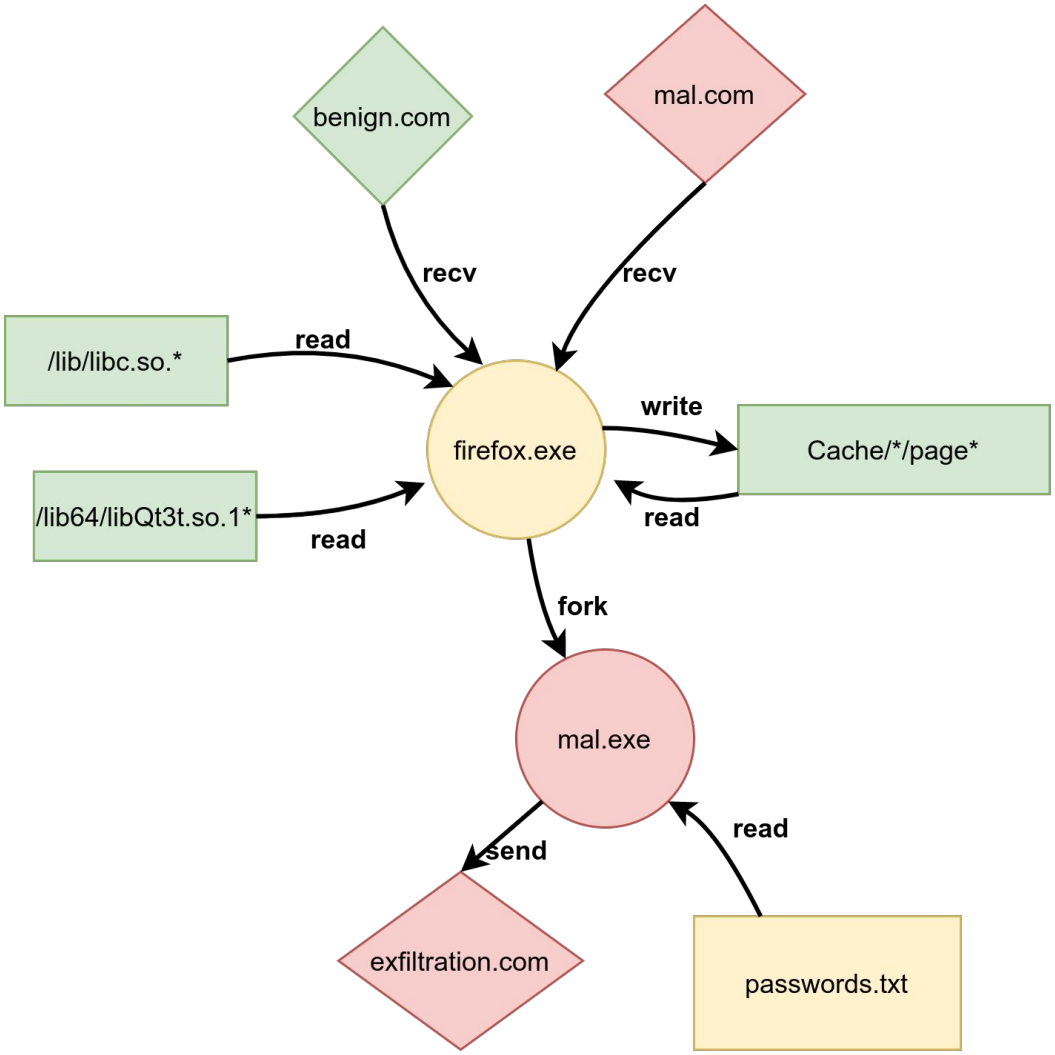
/lib64/libQt3t.so.1*

APPLY



LogApprox

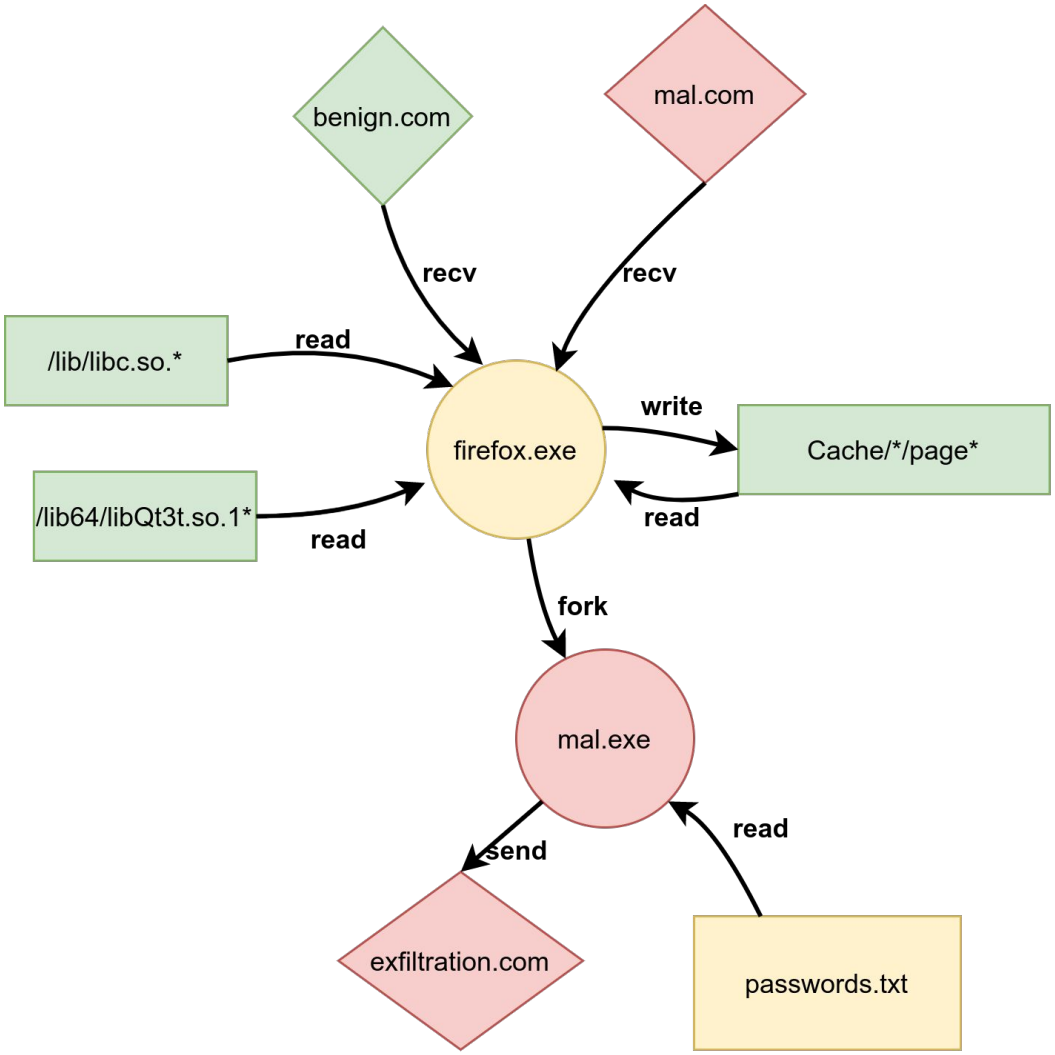
Properties



LogApprox

Properties

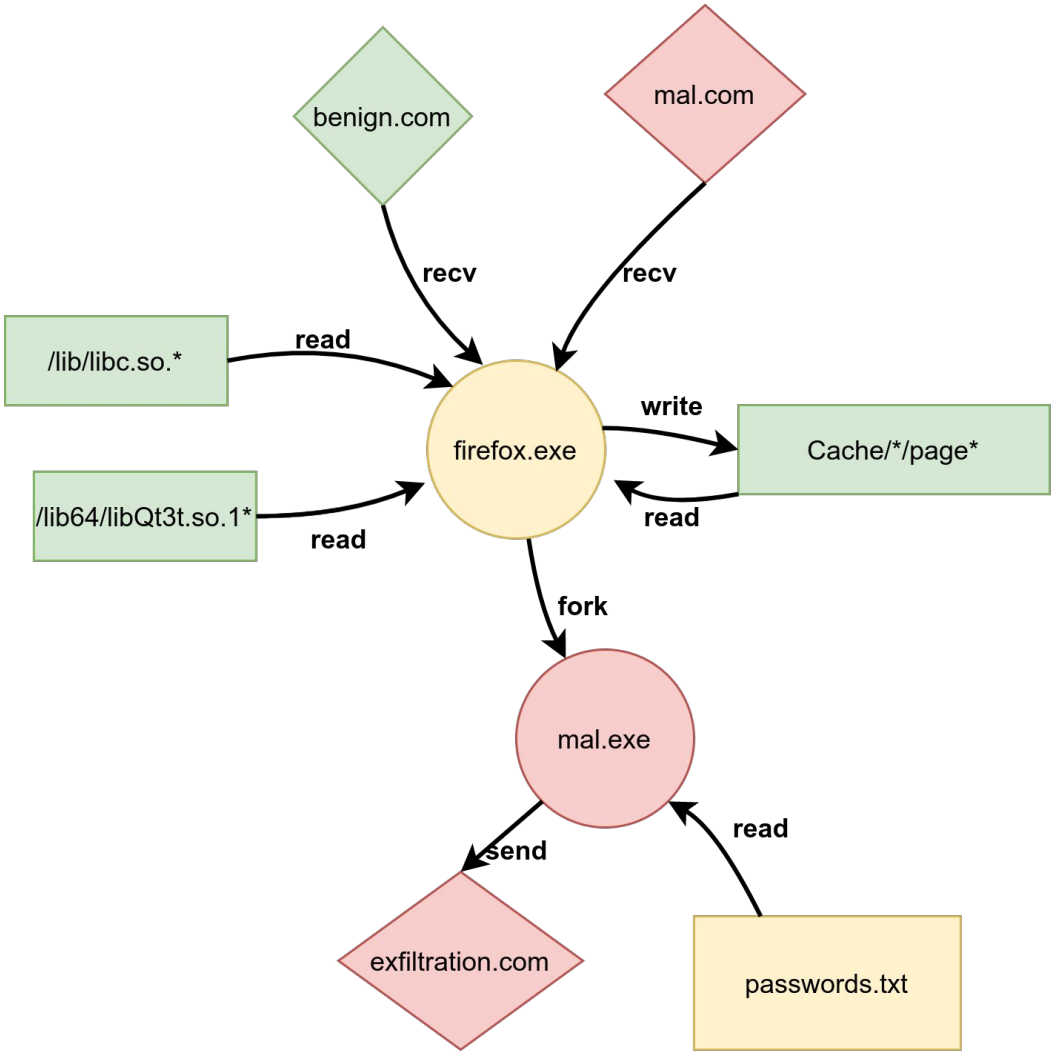
- Only reduces repetitive ***local*** file IO



LogApprox

Properties

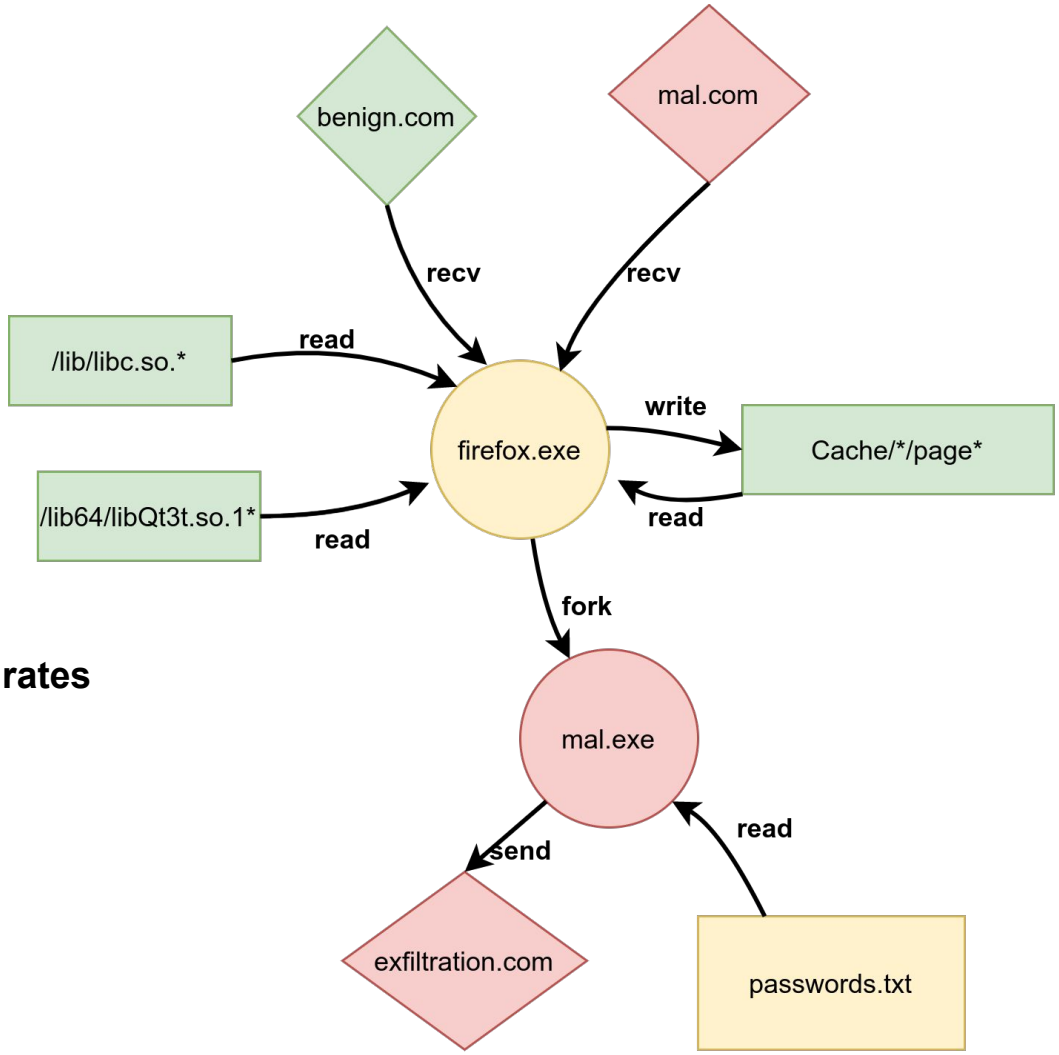
- Only reduces repetitive ***local*** file IO
- IO is only ever ***approximated***



LogApprox

Properties

- Only reduces repetitive ***local*** file IO
- IO is only ever ***approximated***

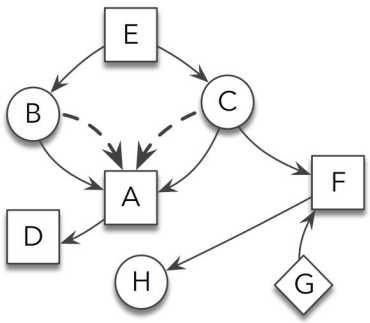


LogApprox can receive high reduction rates while preserving anomalous behavior!

Evaluation against Exemplar Reduction Techniques

Evaluation against Exemplar Reduction Techniques

Causality-Preserving Reduction
by Xu et. al.



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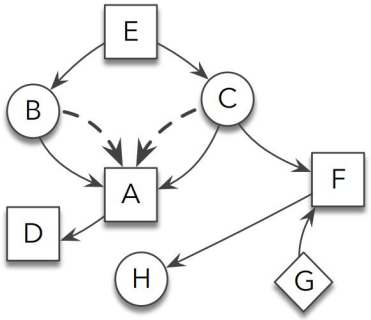
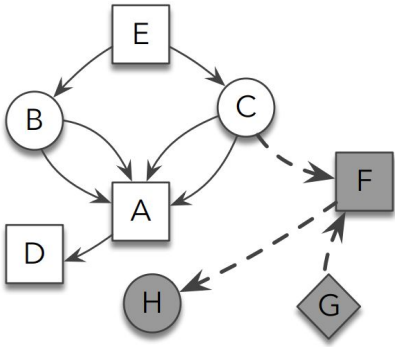


LogGC
by Lee et. al.



Evaluation against Exemplar Reduction Techniques

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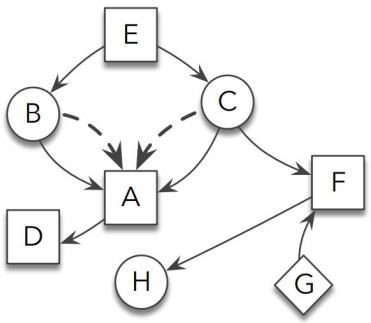

LogGC
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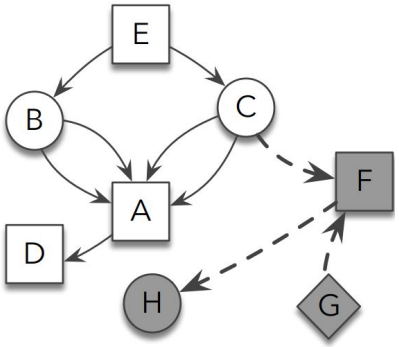
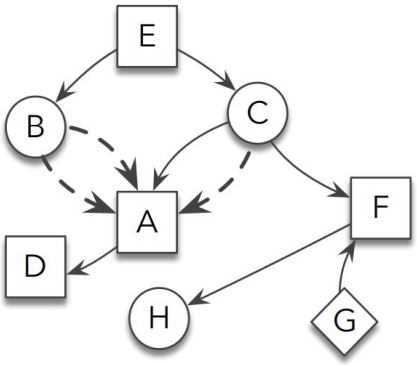
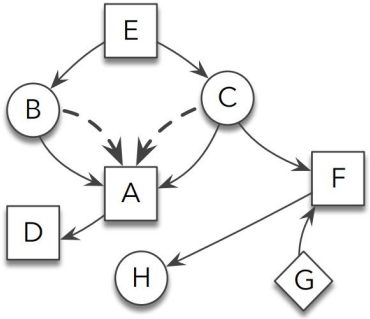


Full and Source Dependence Preserving Reduction
by Hossain et. al

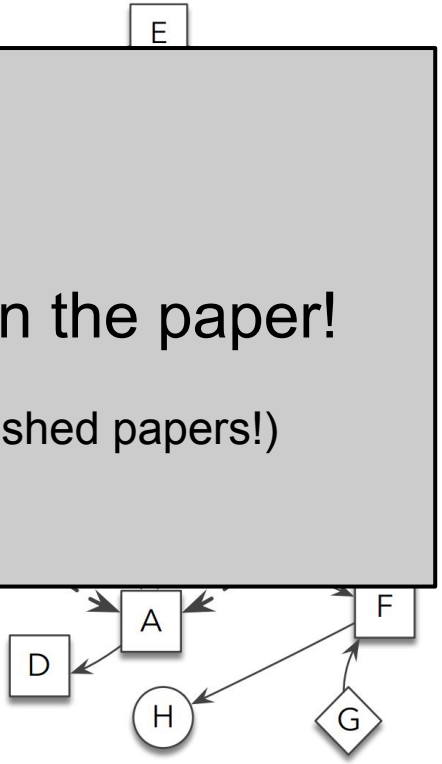


Evaluation against Exemplar Reduction Techniques

Causality-Preserving Reduction
by Xu et. al.



LogGC
by Lee et. al.



Details of each algorithm in the paper!

(and within their respectively published papers!)

Full and Sou
Reduction
by Hossein et. al

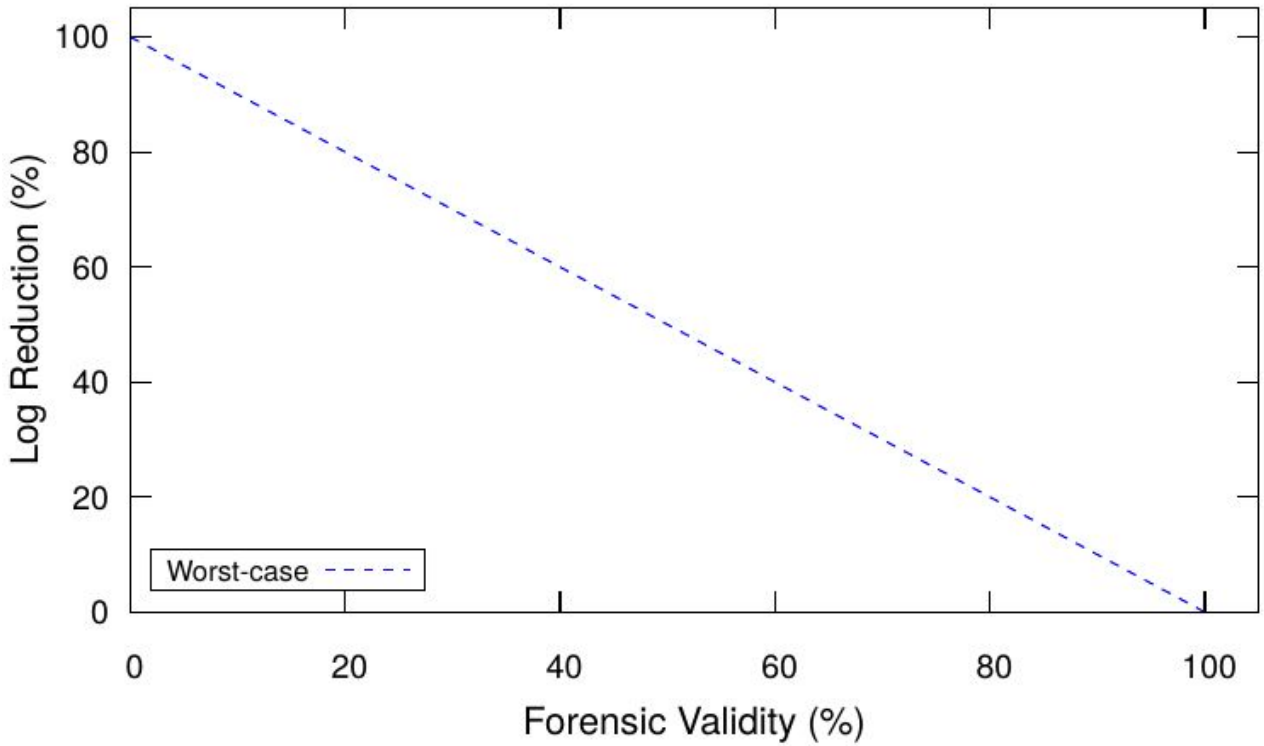
Forensic Evaluation

Curated set of real-world vulnerabilities and exploits:

- unrealircd[1] : IRC Server
- vsftpd[2] : FTP Server
- webmin[3] : System Configuration Tool
- Wordpress[4] : Content Management System
- PHP Webshell[5] : Generic Web Server
- Firefox[6] : Web Browser

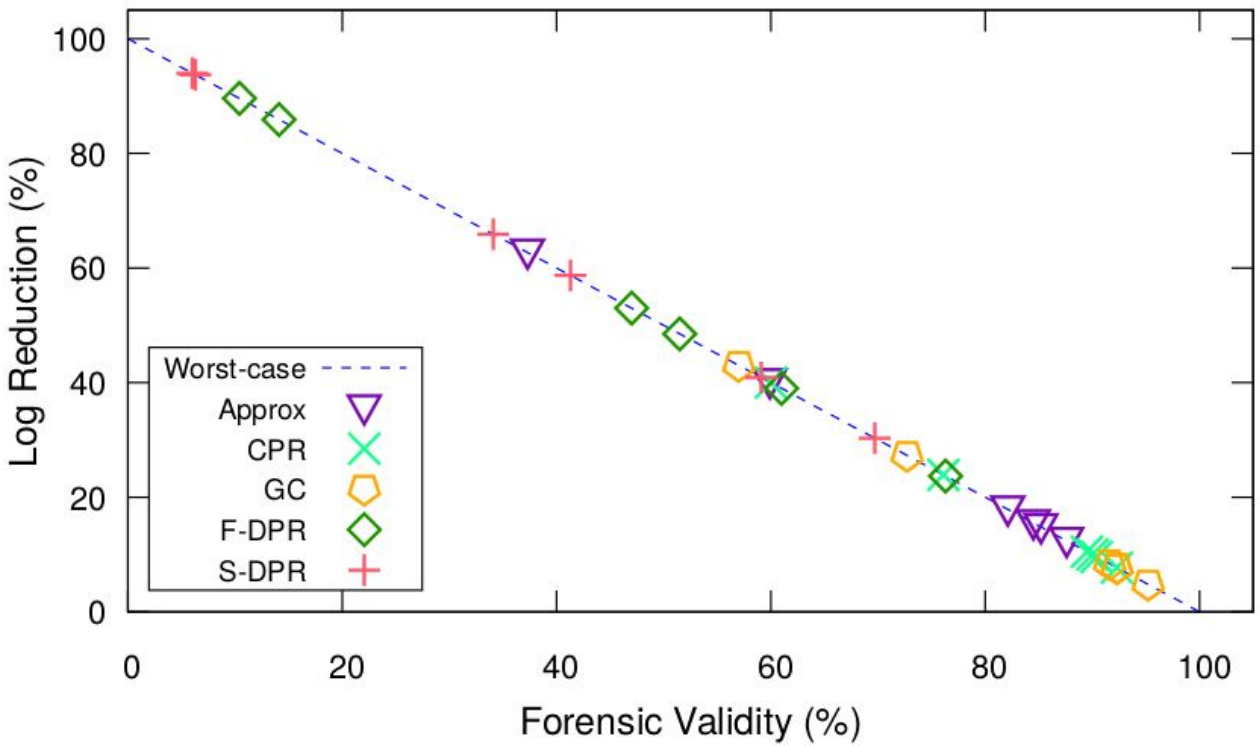
[1] Exploit-DB. 2010. UnrealIRCd 3.2.8.1 - Backdoor Command Execution. [2] Exploit-DB. 2010. UnrealIRCd 3.2.8.1 - Backdoor Command Execution. [3] Exploit-DB. 2019. Webmin 1.920 - Unauthenticated Remote Code Execution [4] Rapid7. 2018. WordPress Admin Shell Upload. [5] Mitre, Server Software Component: Web Shell. Retrieved from https://attack.mitre.org/techniques/T1505/003/, 2019
[6] A. D. Keromytis, “Transparent computing engagement 3 data,” https://github.com/darpa-i2o/Transparent-Computing, 2018,

Results


100
80
60
40
20
0
Log Reduction (%)
Worst-case
0
20
40
60
80
100
Forensic Validity (%)

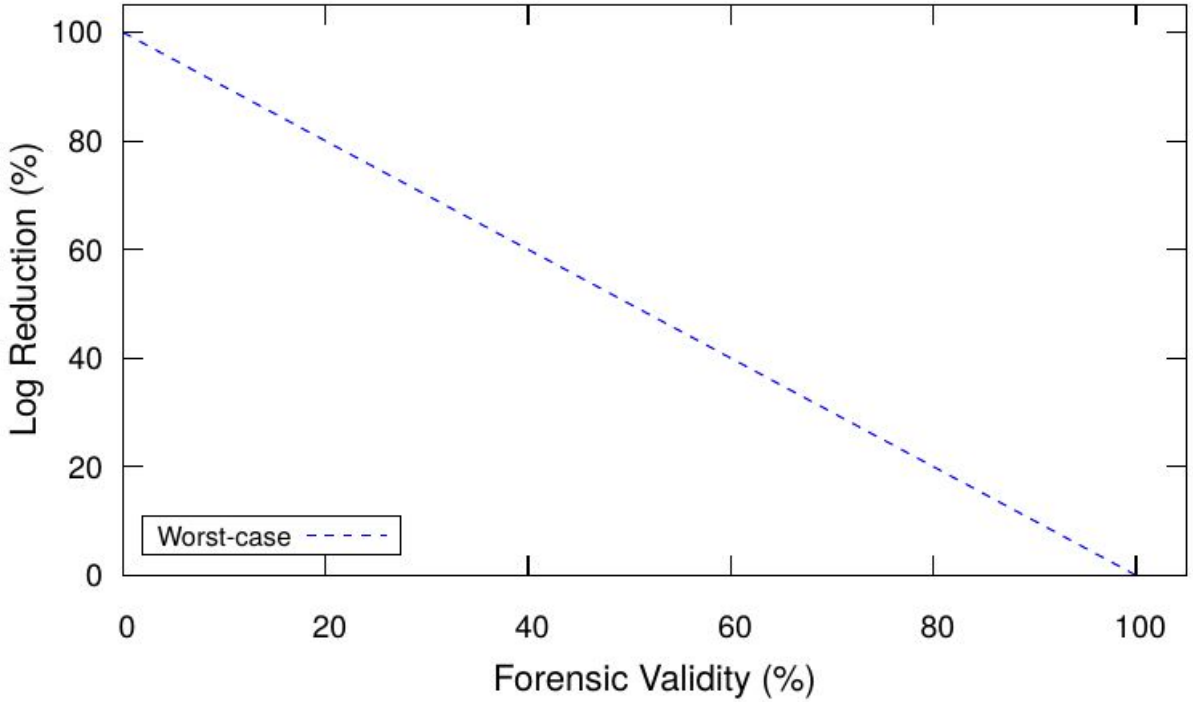
Results

Lossless Forensics



Results

Causality-Preserving Forensics
(all information flow)



Results

Causality-Preserving Forensics
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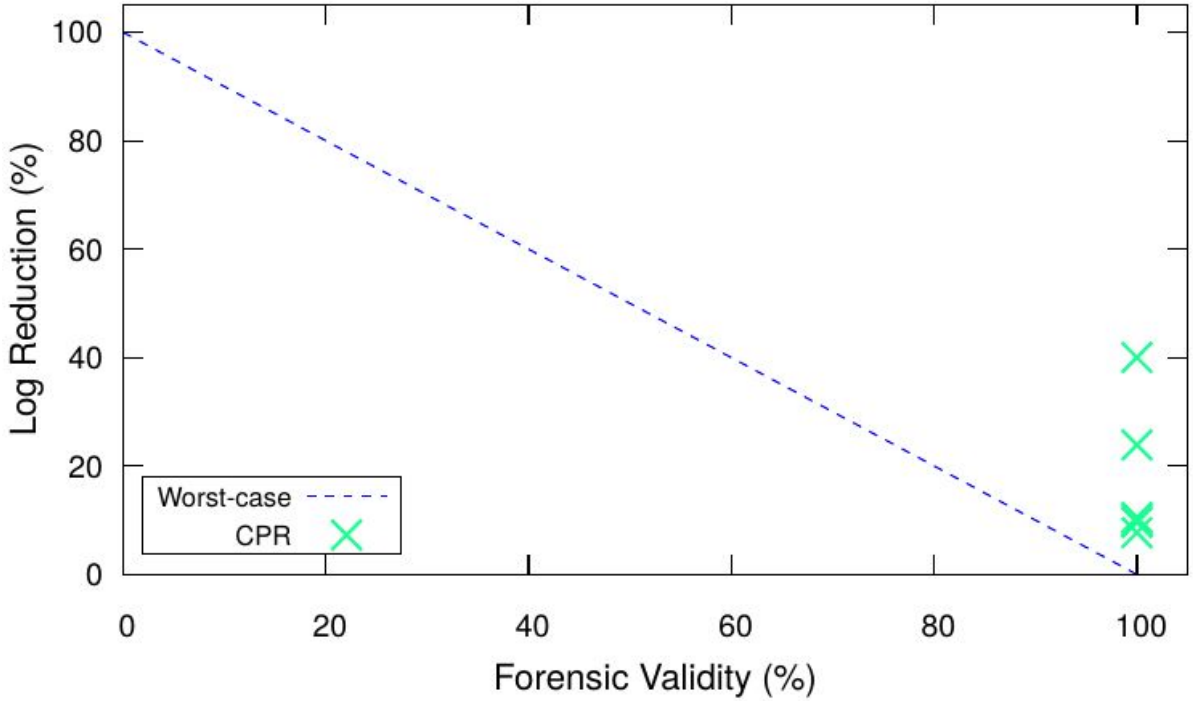

Results

Causality-Preserving Forensics
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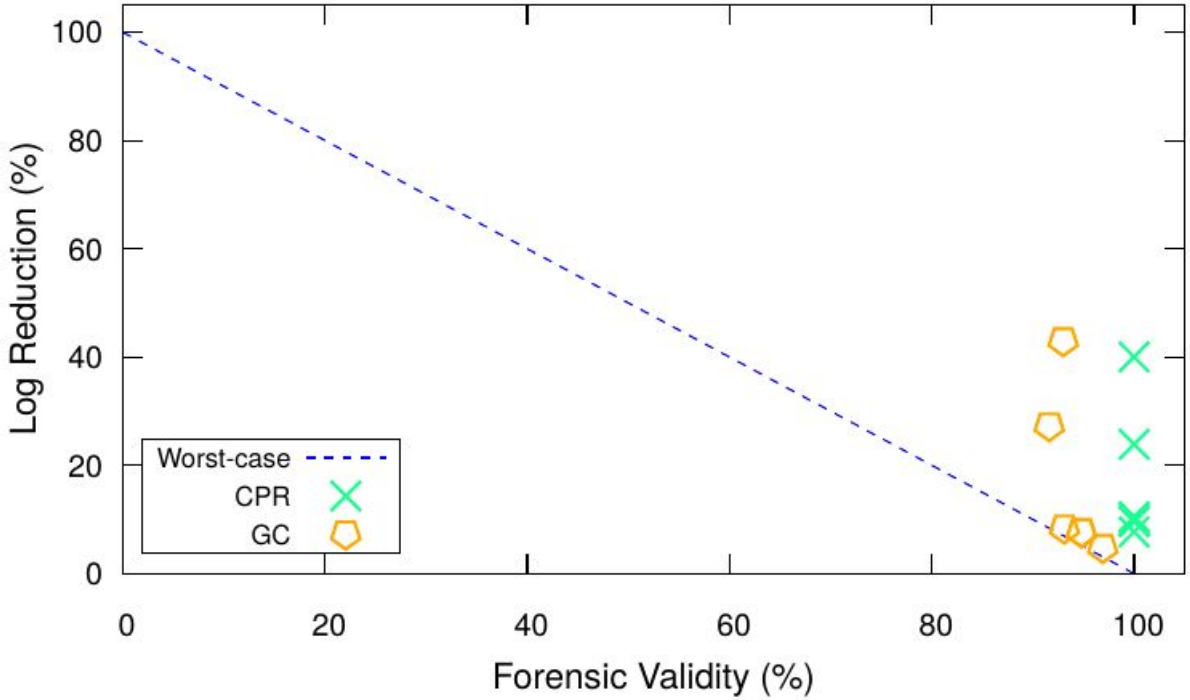
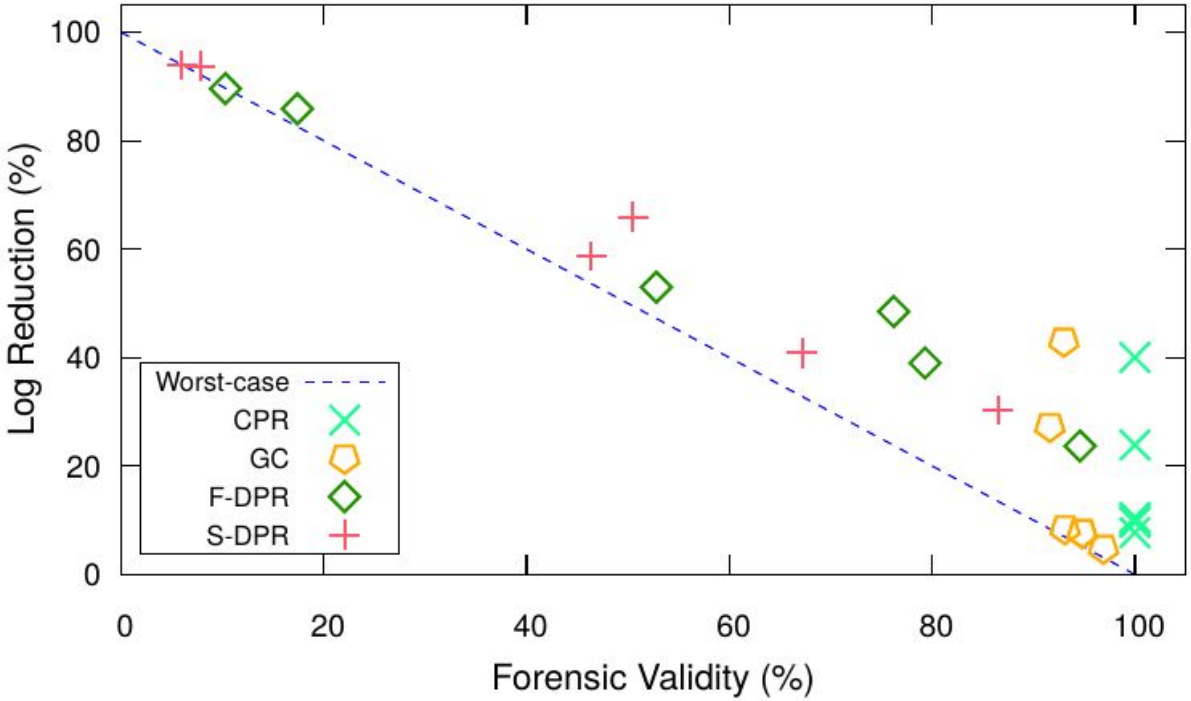


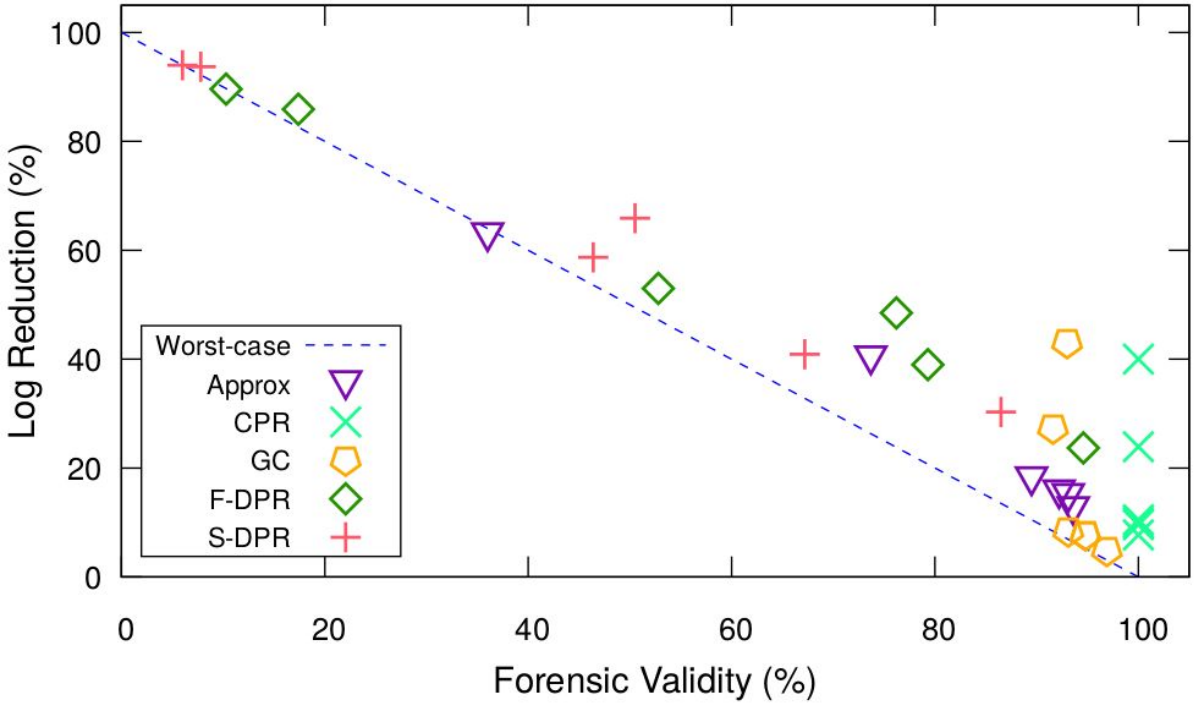
Results

Causality-Preserving Forensics
(all information flow)



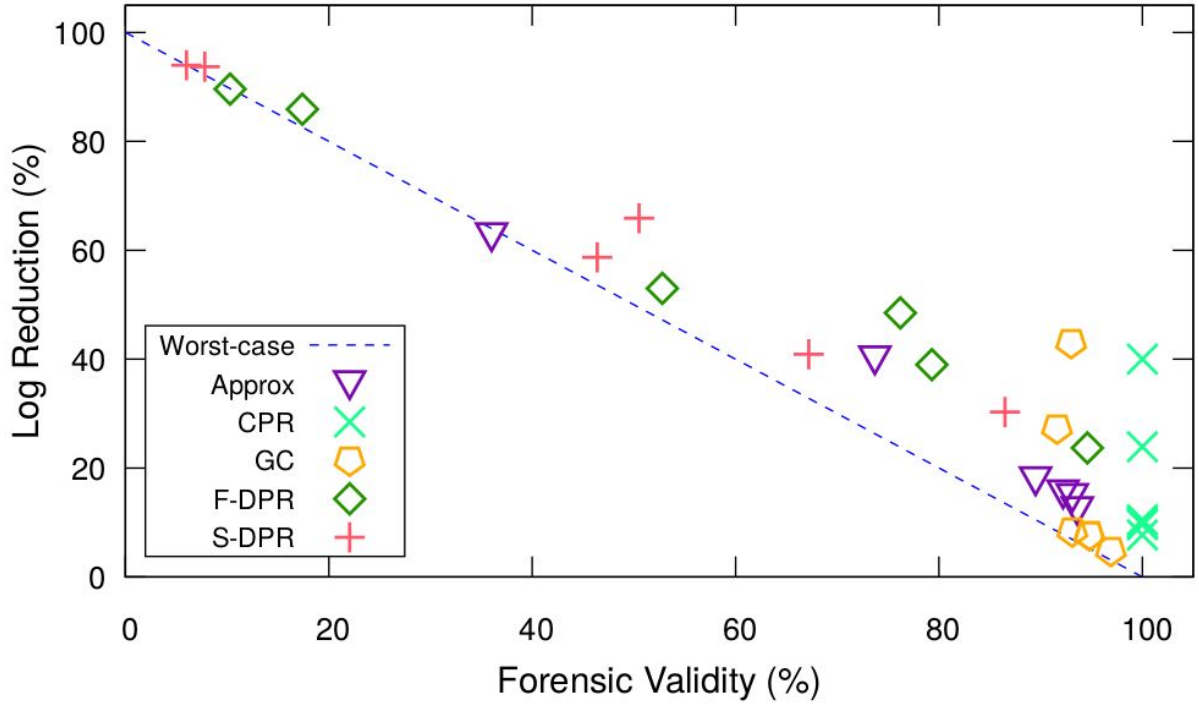
Results

Causality-Preserving Forensics
(all information flow)

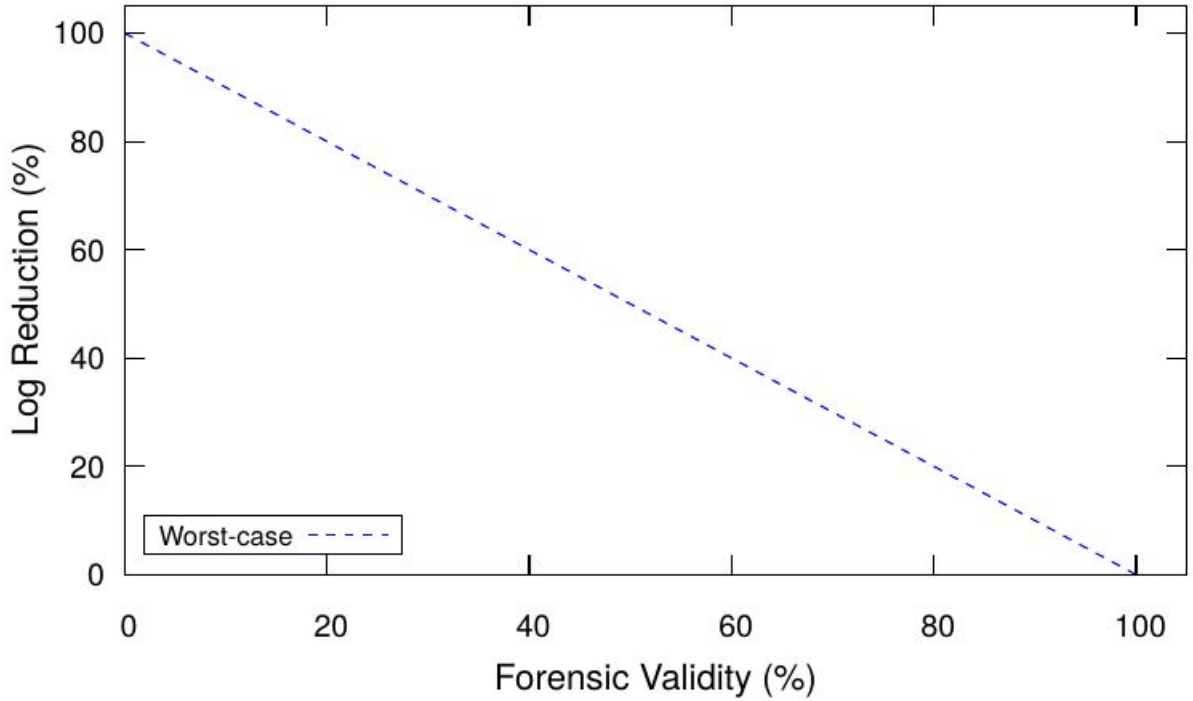


Results

Causality-Preserving Forensics
(all information flow)

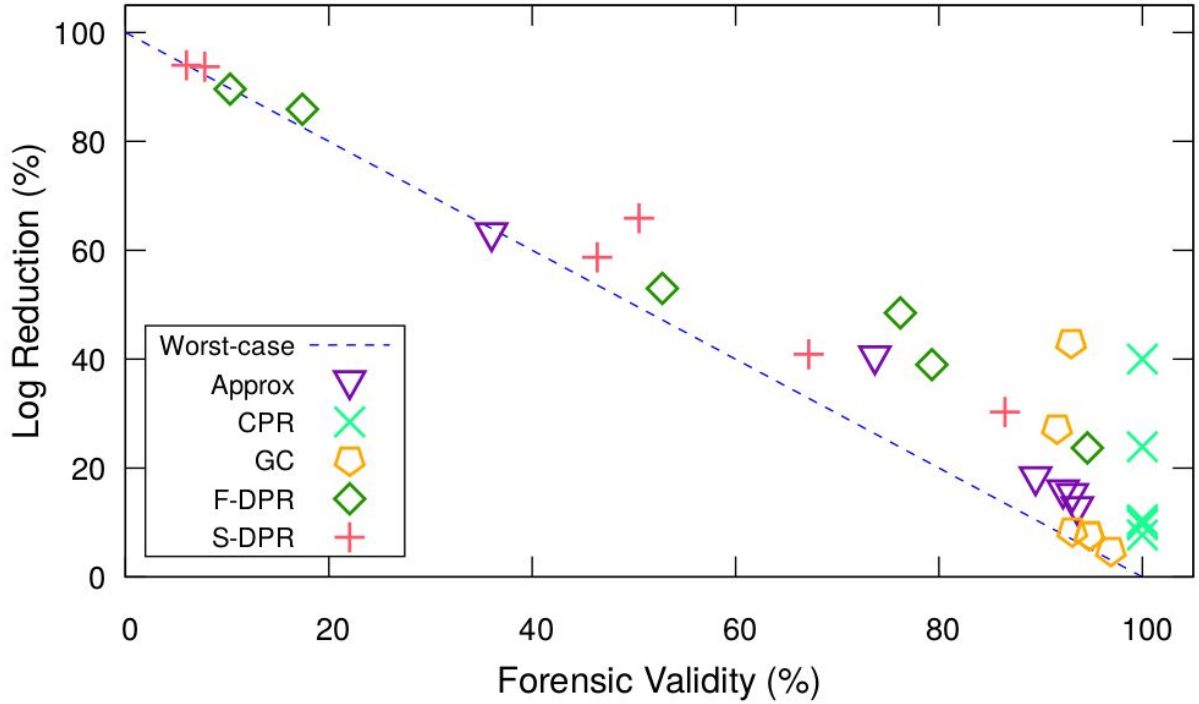


Attack-Preserving Forensics
(uniquely malicious information flow)



Results

Causality-Preserving Forensics
(all information flow)



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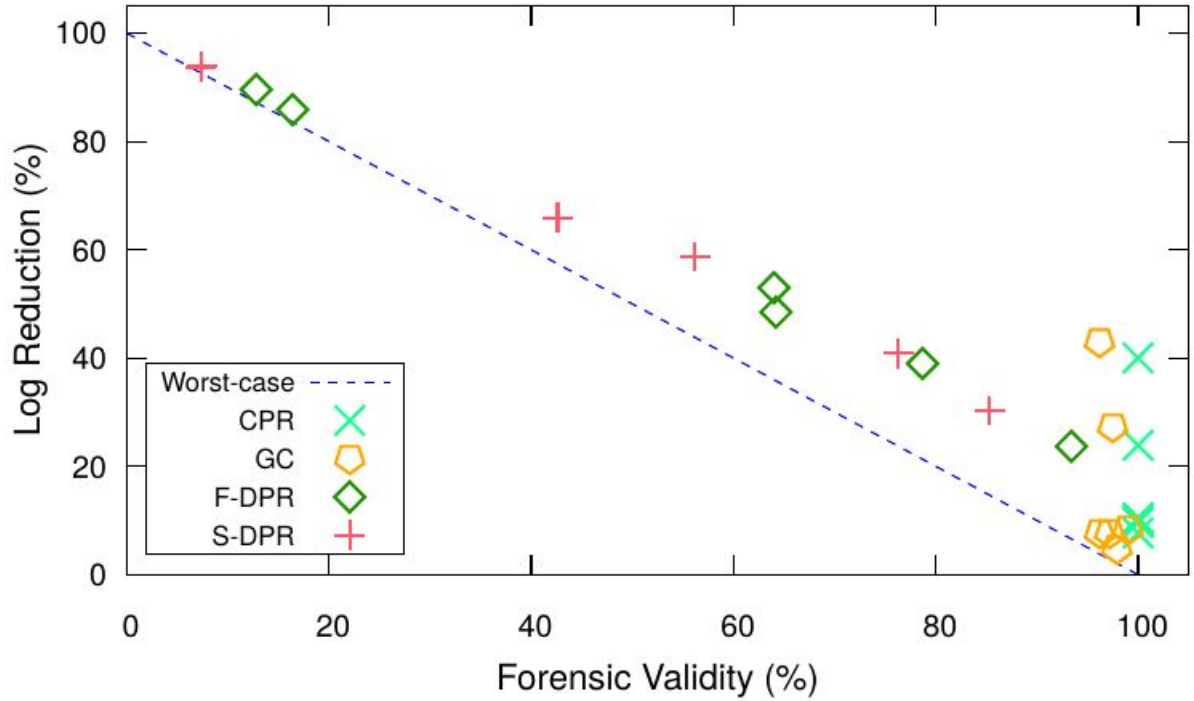
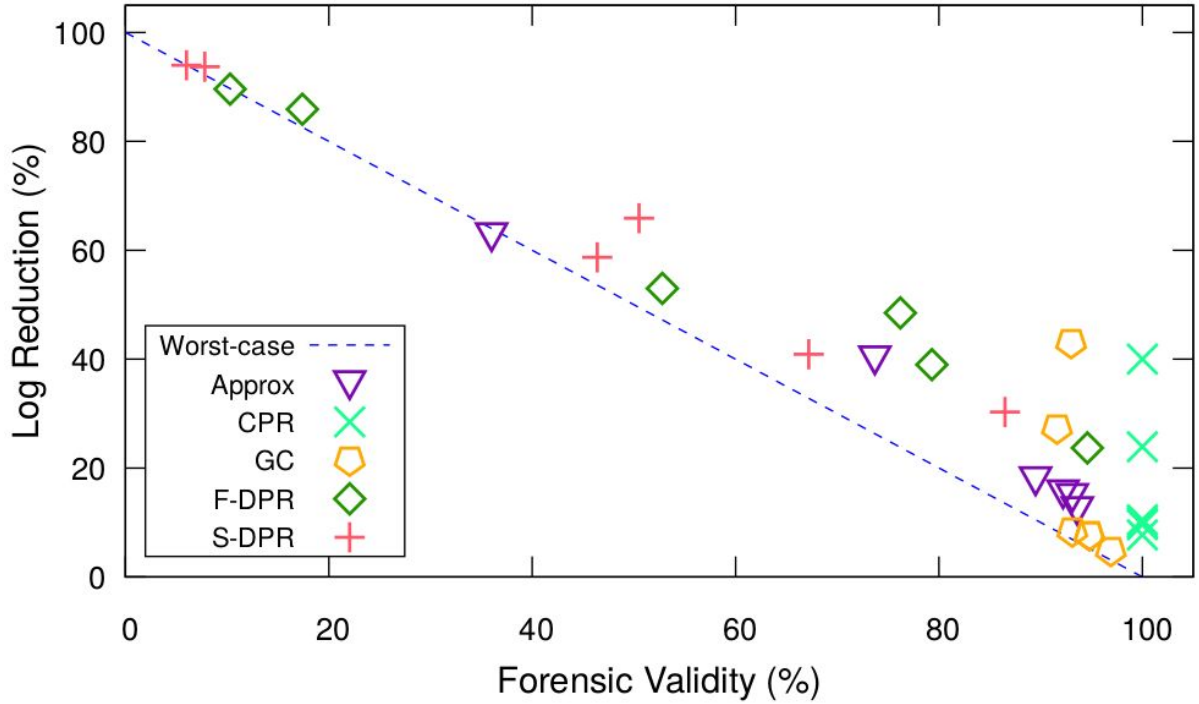
(uniquely malicious information flow)

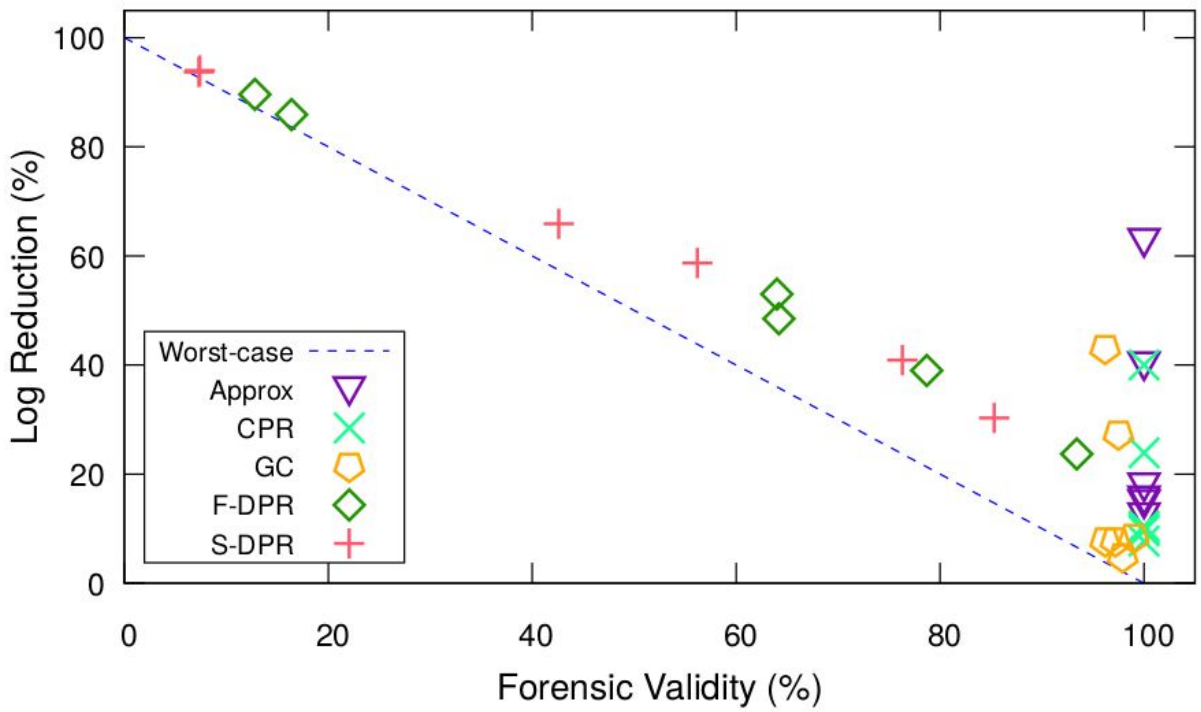


Results

Causality-Preserving Forensics
(all information flow)



Attack-Preserving Forensics
(uniquely malicious information flow)



Takeaways

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Validity of reduced logs should **not** be based on anecdotal studies

- Depends on **task** and **threat model**
- Providing a continuous metric for arbitrary queries is a step in the right direction

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Validity of reduced logs should **not** be based on anecdotal studies

- Depends on **task** and **threat model**
- Providing a continuous metric for arbitrary queries is a step in the right direction

Reduction techniques can be tailored to specific tasks and threats

- Tasks: Source and Full Dependency Preserving
- Threat Models: **LogApprox**

Thank You!