Secure Cloud Storage
&
Best Senior Project Story

ALPTEKİN KÜPÇÜ

Associate Professor of Computer Science and Engineering

Ph.D. Brown University

KOÇ
UNIVERSITY

Alptekin Küpçü

- B.S., Bilkent University, 2000-2004
- Ph.D., Brown University, 2004-2010
- Faculty, Koç Üniversitesi, 2010-
  - 3 post-doctoral researcher alumni
  - 4 phd & 4 ms student alumni
    - EPFL Switzerland, KU Leuven Belgium, University of Virginia USA, LinkedIn USA, NTU Singapore, Dapper Labs Canada
  - Hiring for blockchain project (2 phd, 2 ms, 1 post-doctoral)
- Visiting Scholar
  - METU , 2020
  - Bilkent University, TOBB ETU, IZTECH, 2019
  - Microsoft Research, 2013 & 2015
  - Yahoo! Labs, 2015

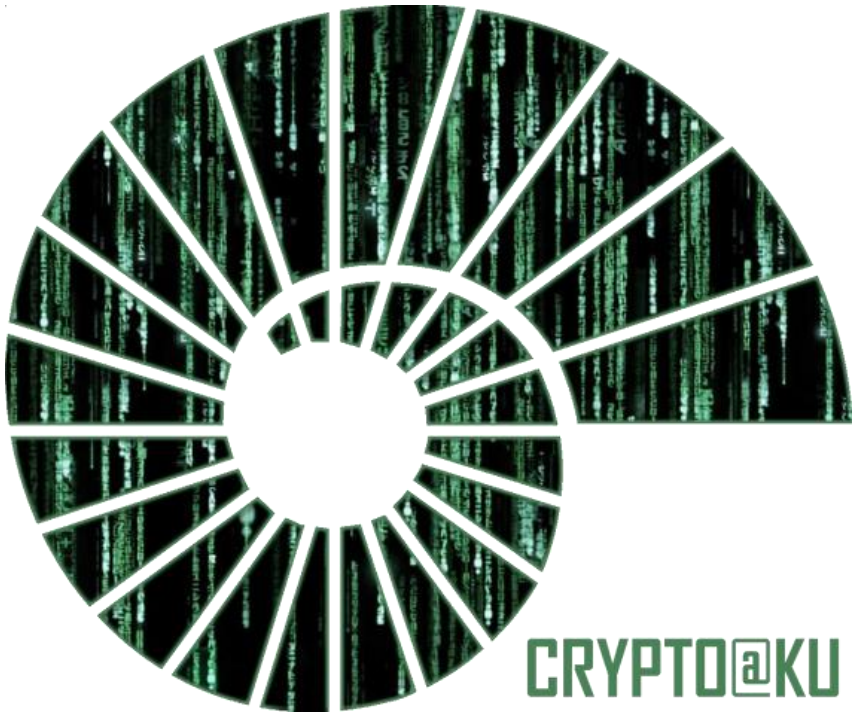
Collaborations & Awards

- UCL, UK
- Maryland University, Virginia University, Brown University, Northeastern University, Rutgers University, USA
- EPFL, Switzerland
- Salzburg University, Austria
- KU Leuven, Belgium
- Bilkent University, Ege University, Turkey
- Microsoft Research, Yahoo! Labs, IBM Research, USA
- TEB, IDEA, Koç Sistem, Türk Telekom, Turkey

- Science Academy, BAGEP outstanding young scholar
- Turkish Academy of Sciences, GEBİP outstanding young scholar
- ODTÜ Parlar Foundation, Research Encouragement Award
- Royal Society of UK, Newton Advanced Fellowship
- IEEE Senior Member
- ACM Senior Member
- 4 teaching awards from Koç University
- 6 international patents

Cryptography, Security, and Privacy Research Group

- **Core Research**
  - Cryptography
  - Security
  - Privacy
- **Application Areas**
  - Cloud Computing
  - Passwords and Authentication
  - Smart Homes and IoT
  - Peer-to-peer Systems
  - Blockchain Applications
  - E-ID and E-Health Systems
  - Game Theory and Mechanism Design
  - Provable Security
  - ...



Goal

Cryptographic protocols can efficiently and scalably be used to provide security and privacy for the next generation systems.

Overview

- **Secure Cloud Storage**
  - **Problems**
  - **Solutions**
  - **Summary**

Overview

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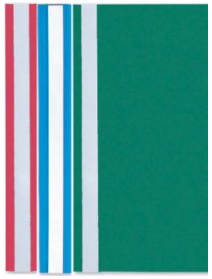
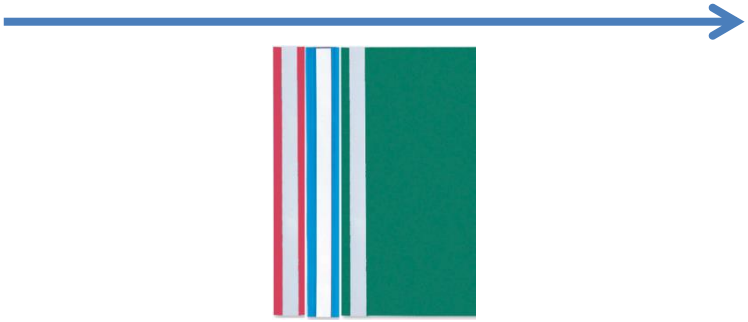
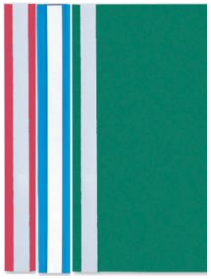
Outsourced Storage



Outsourced Storage



Outsourced Storage



Untrusted Storage

INTEGRITY

Untrusted Storage

INTEGRITY

Untrusted Storage

CONFIDENTIALITY

Overview

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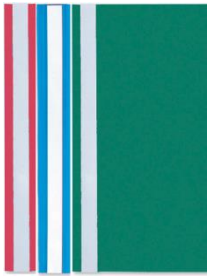
Confidentiality



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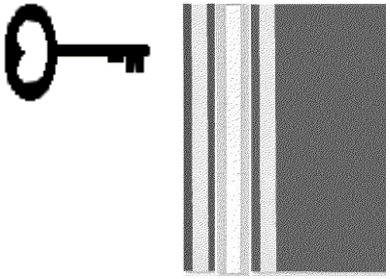
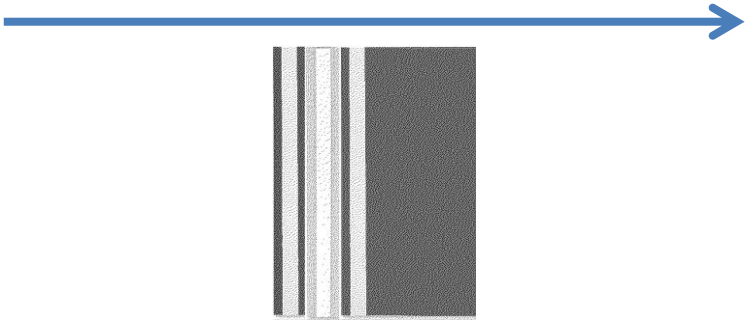


ENCRYPT

Confidentiality



Confidentiality

Integrity: Naïve Solution 1

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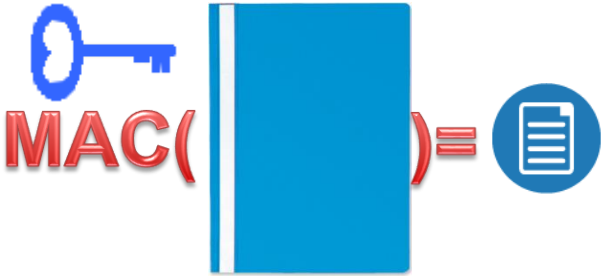
Integrity: Naïve Solution 2



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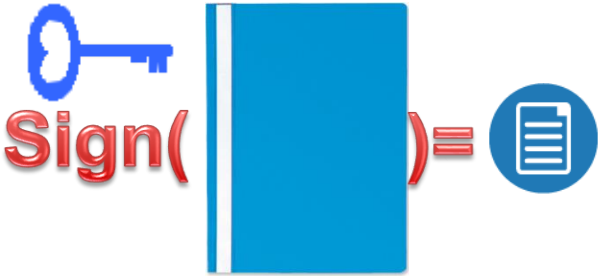

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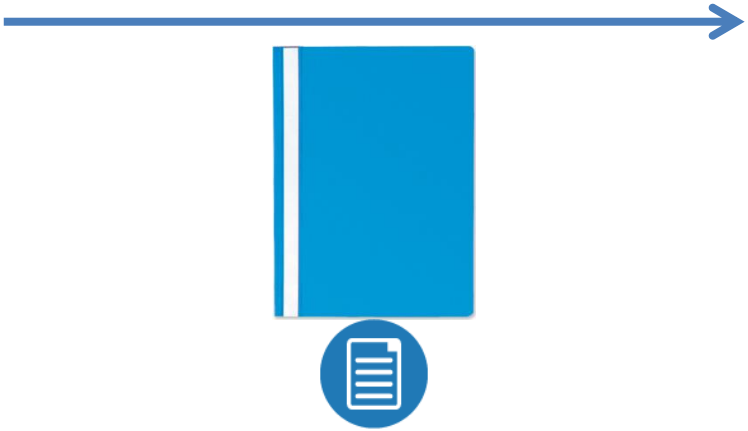

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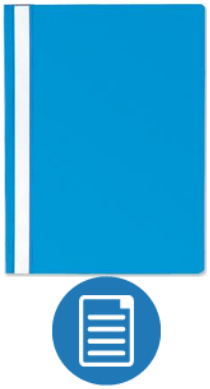

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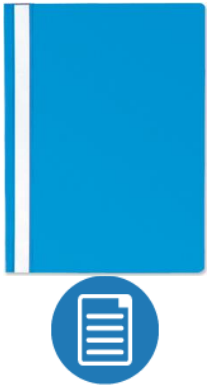

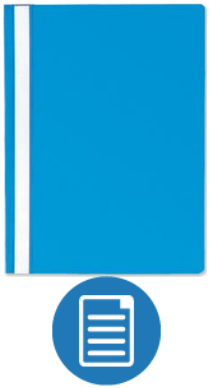

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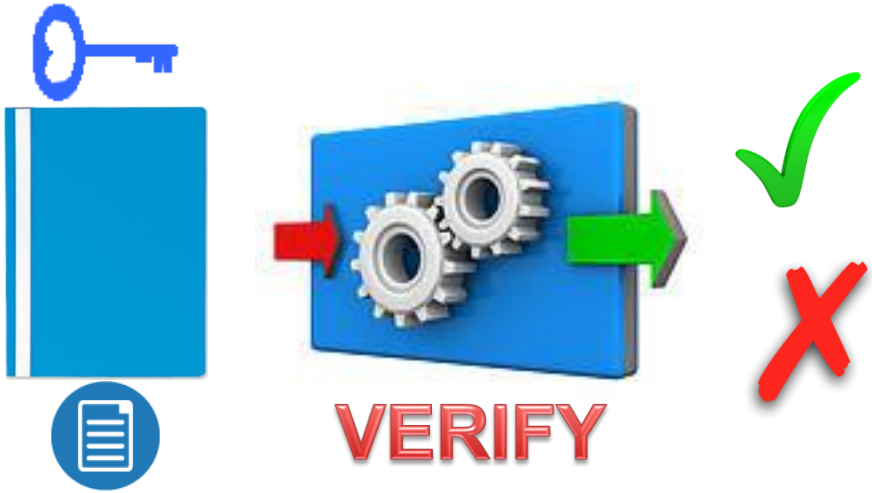
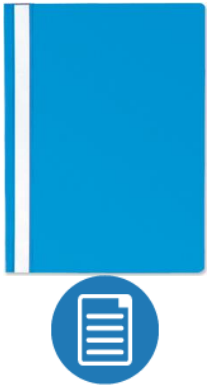
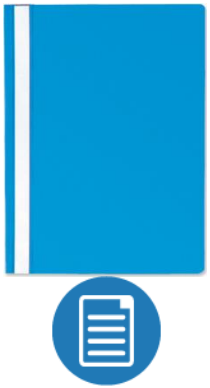


Problem with Naïve Approaches





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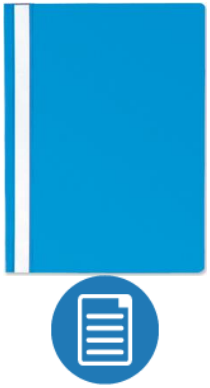

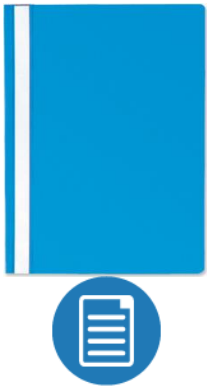

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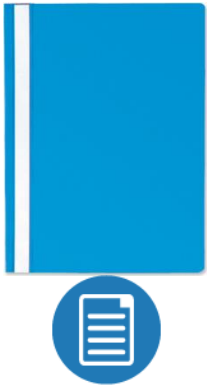

Overview

- **Secure Cloud Storage**
  - **Problems**
  - **Efficient Solutions**
  - **Summary**

Provable Data Possession

[ABCHKPS ACM CCS 2007]

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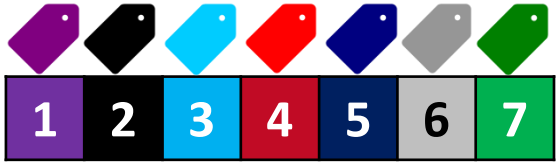

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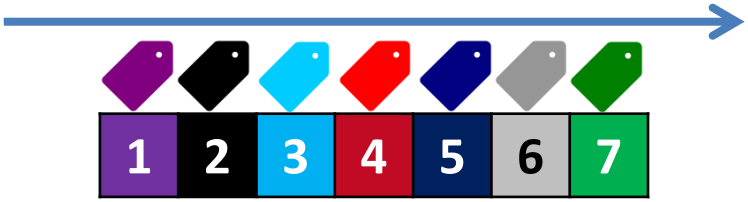

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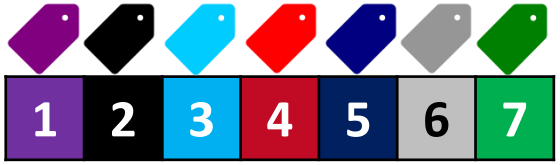

Provable Data Possession

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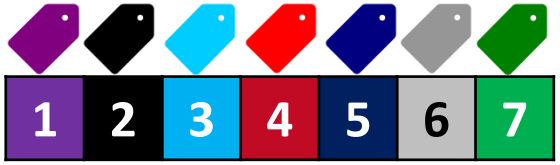
CHALLENGE: 1 4 7



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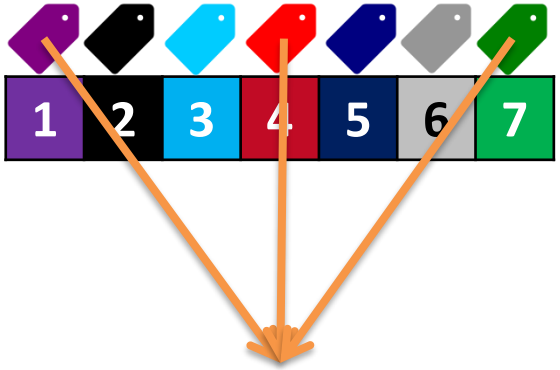

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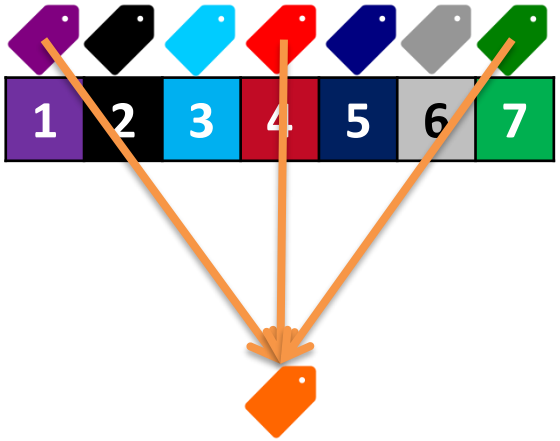

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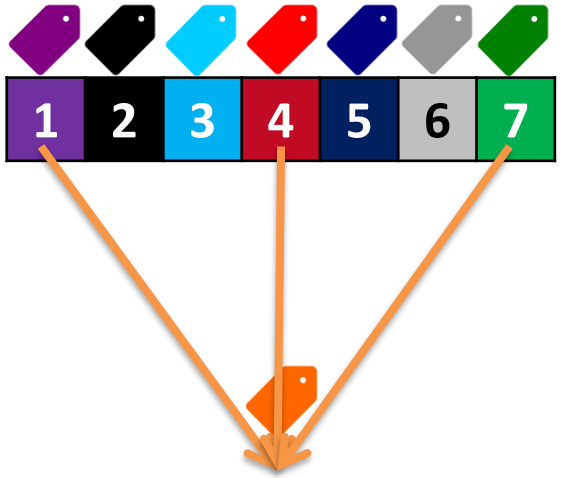

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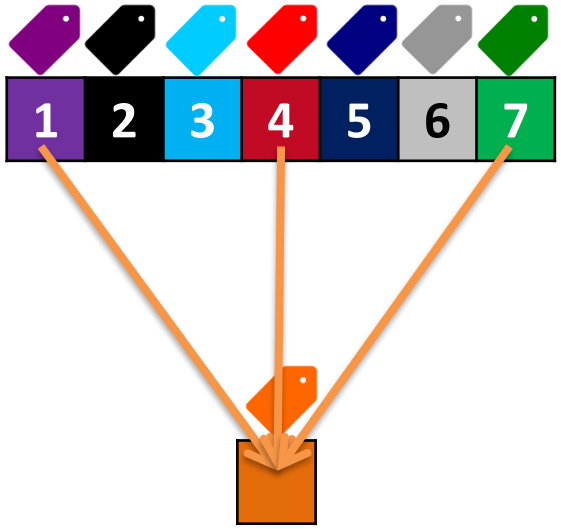

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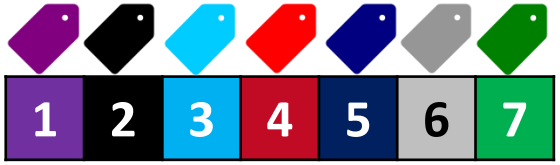

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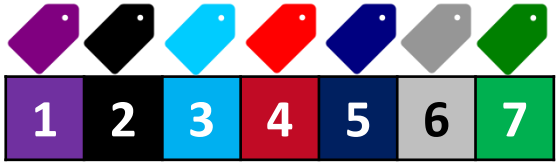

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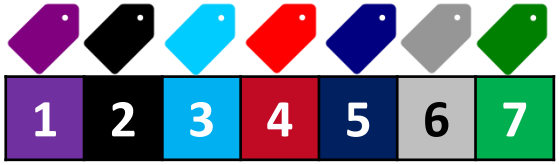
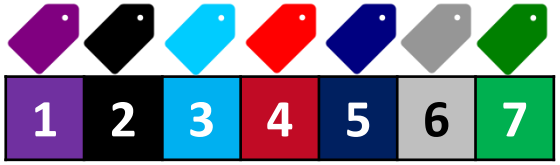


PDP is for Static Data

CHALLENGE: 4



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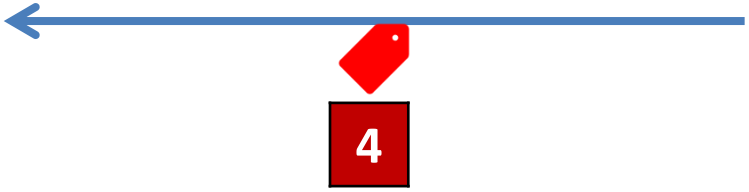

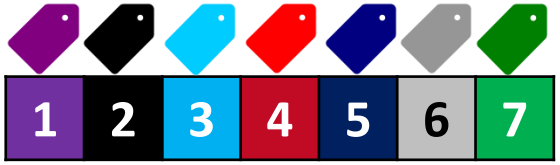

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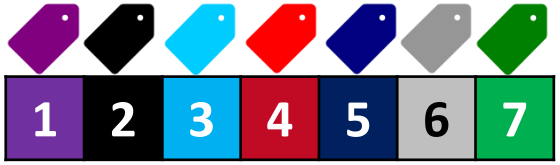

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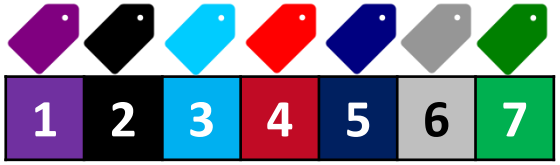

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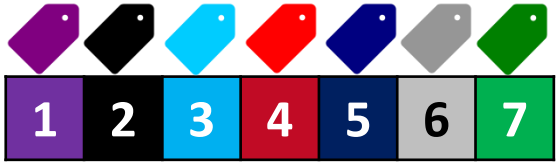

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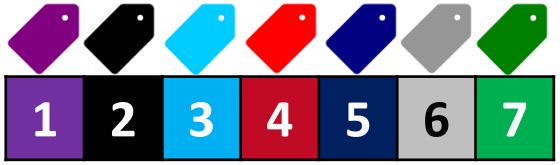

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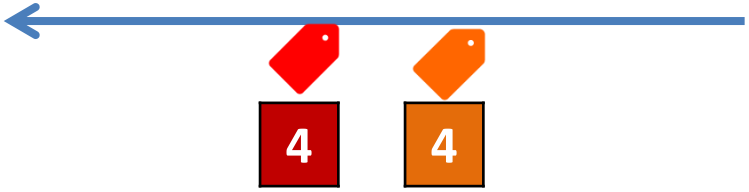

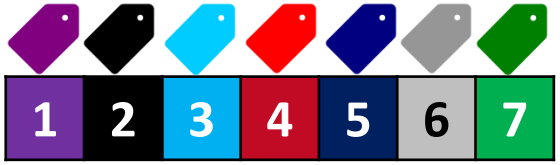

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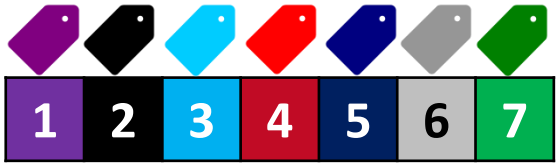

PDP is for Static Data

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- **Secure Cloud Storage**
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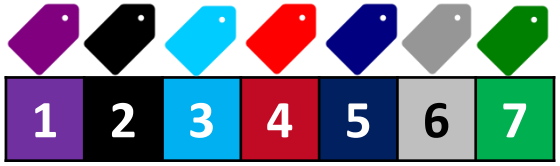
  - **Efficient Dynamic Solutions**
  - **Summary**

Dynamic Provable Data Possession

[EKPT ACM CCS 2009 & ACM TISSEC 2015]



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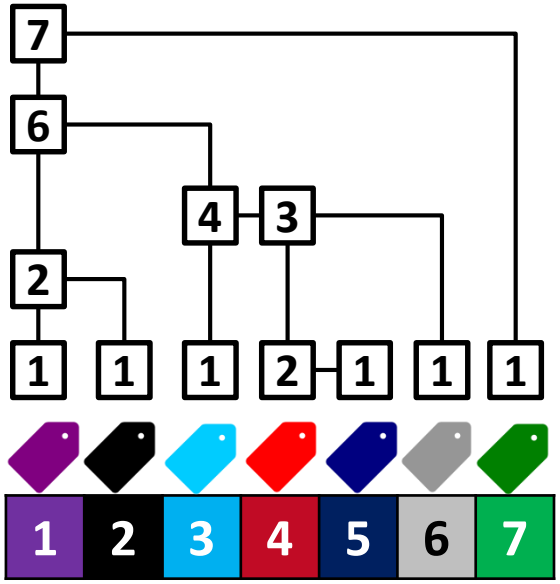
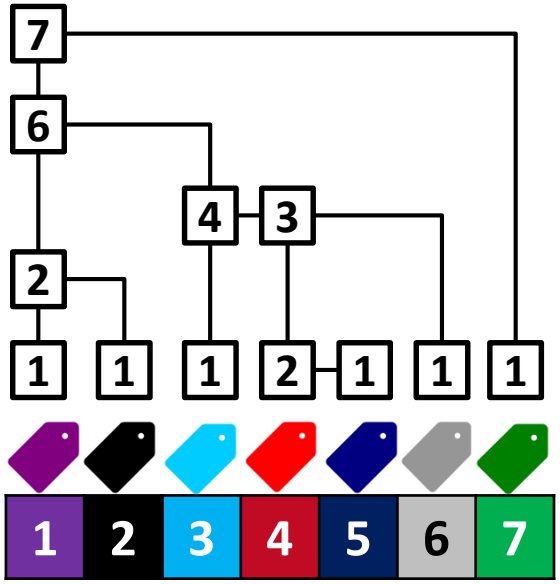


Rank-Based Authenticated Skip List

Dynamic Provable Data Possession

[EKPT ACM CCS 2009 & ACM TISSEC 2015]

Search for 5

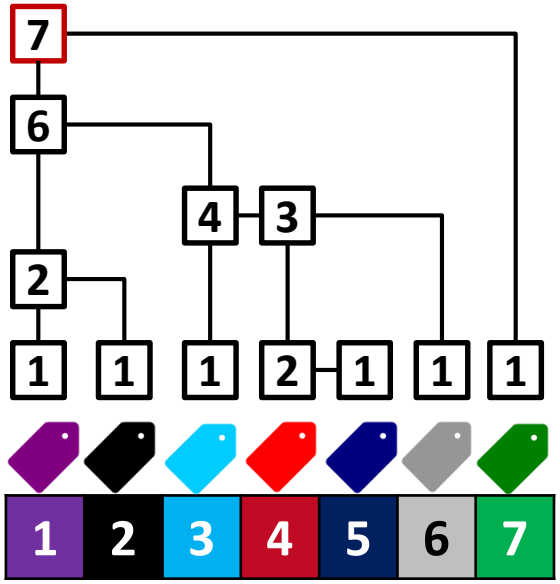


Rank-Based

Dynamic Provable Data Possession

[EKPT ACM CCS 2009 & ACM TISSEC 2015]

Search for 5



Dynamic Provable Data Possession

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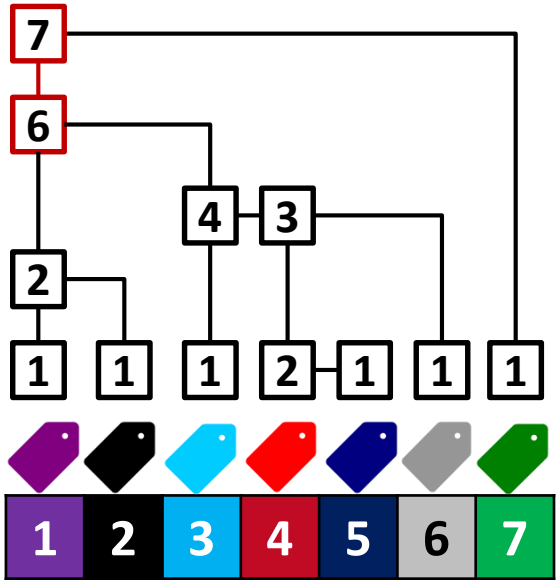
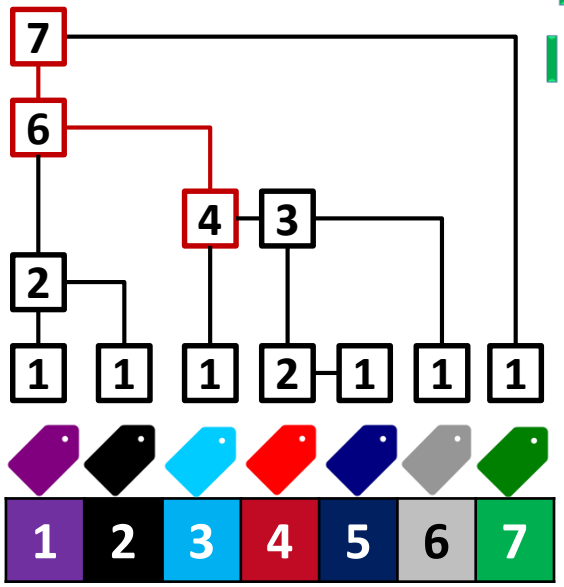


Dynamic Provable Data Possession

[EKPT ACM CCS 2009 & ACM TISSEC 2015]

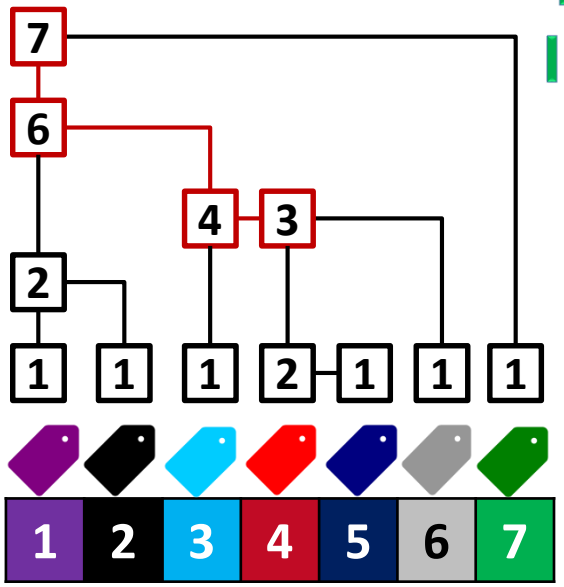
CONTINUE SEARCHING,
BUT SEARCH FOR 5-2=3
IN THE REMAINING PART



Dynamic Provable Data Possession

[EKPT ACM CCS 2009 & ACM TISSEC 2015]

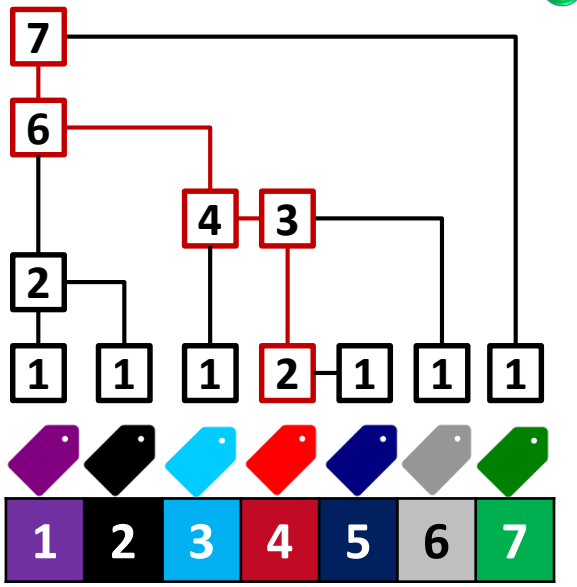
CONTINUE SEARCHING, BUT SEARCH FOR 3-1=2 IN THE REMAINING PART



Dynamic Provable Data Possession

[EKPT ACM CCS 2009 & ACM TISSEC 2015]

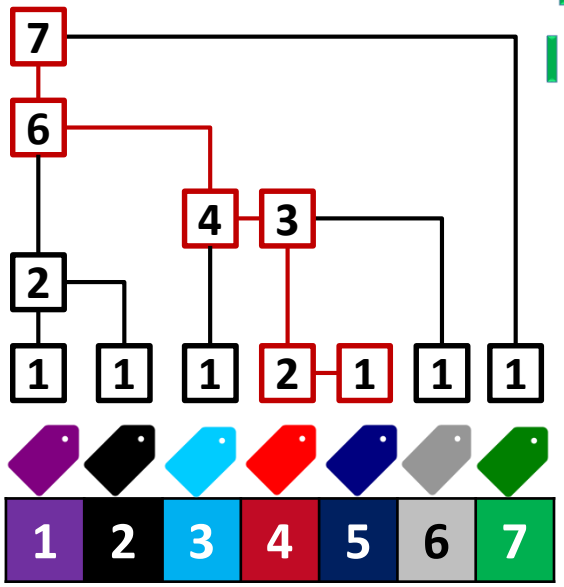
CONTINUE SEARCHING 2



Dynamic Provable Data Possession

[EKPT ACM CCS 2009 & ACM TISSEC 2015]

CONTINUE SEARCHING,
BUT SEARCH FOR 2-1=1
IN THE REMAINING PART



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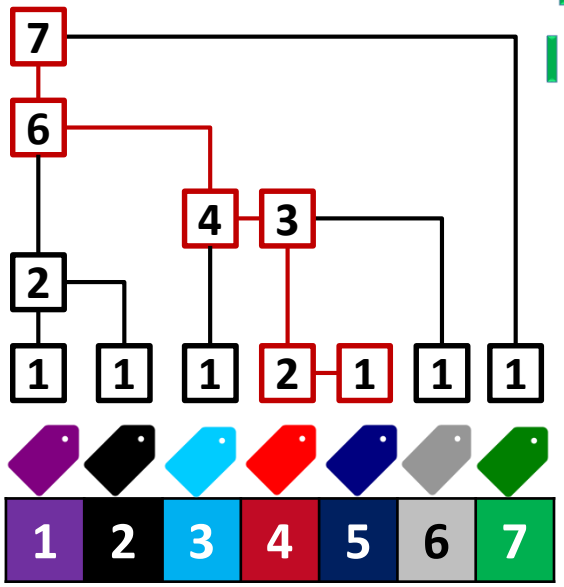
[EKPT ACM CCS 2009 & ACM TISSEC 2015]



CONTINUE SEARCHING, BUT SEARCH FOR 2-1=1 IN THE REMAINING PART

SEARCH FOR 1 MEANS FOUND IT

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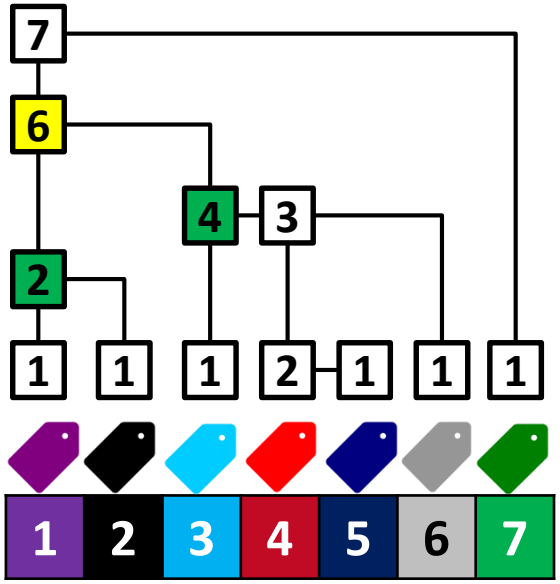
[EKPT ACM CCS 2009 & ACM TISSEC 2015]



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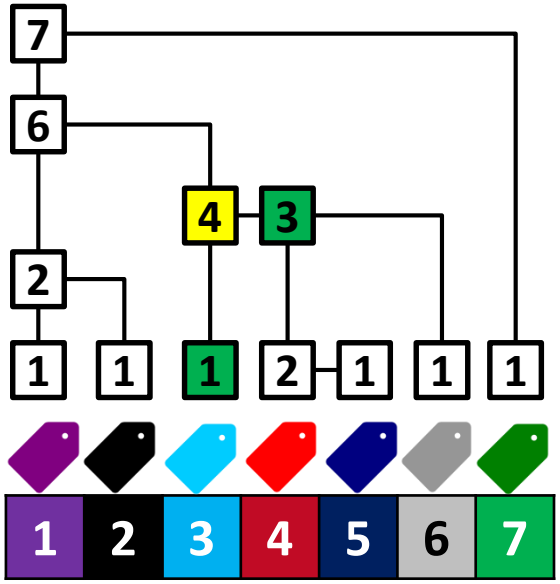

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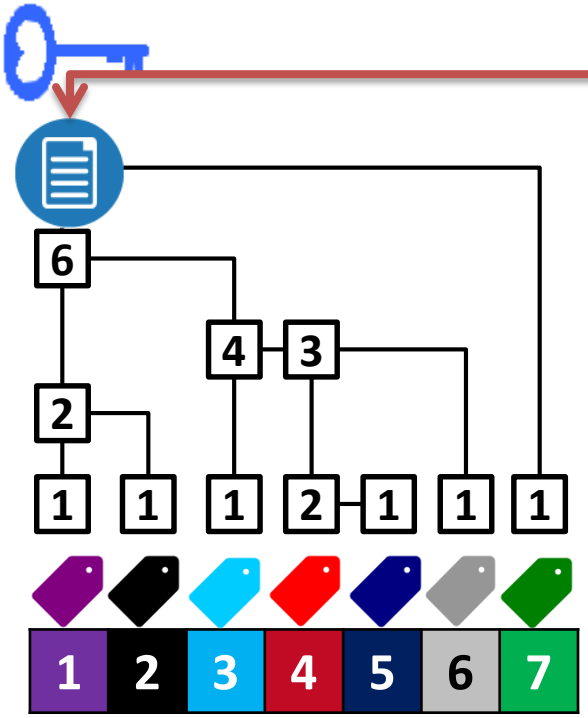

Digest (Metadata)

Rank-Based Authenticated Skip List

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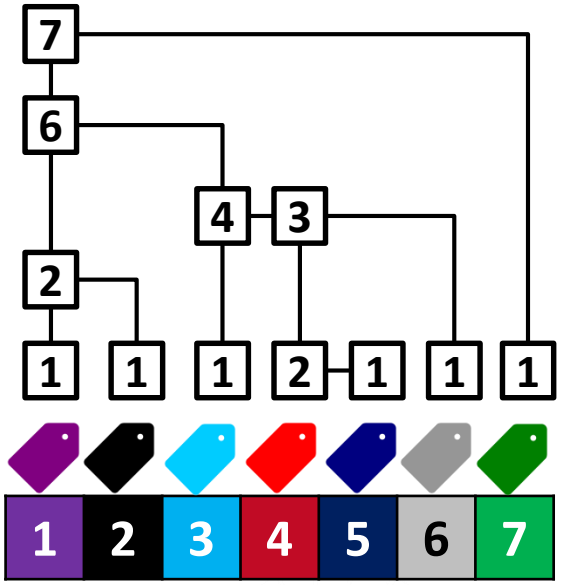

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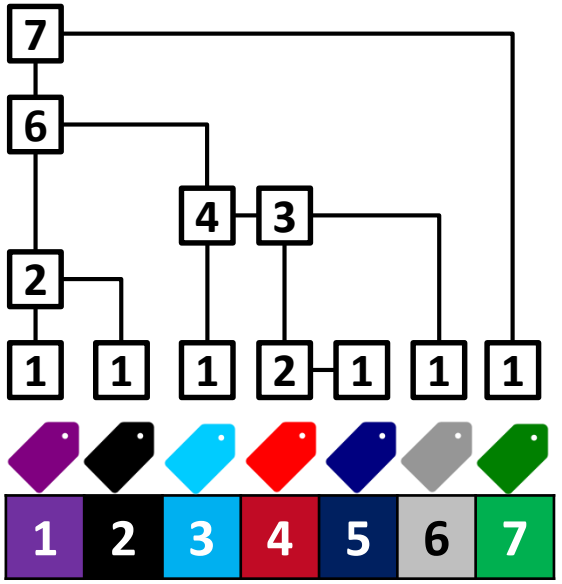

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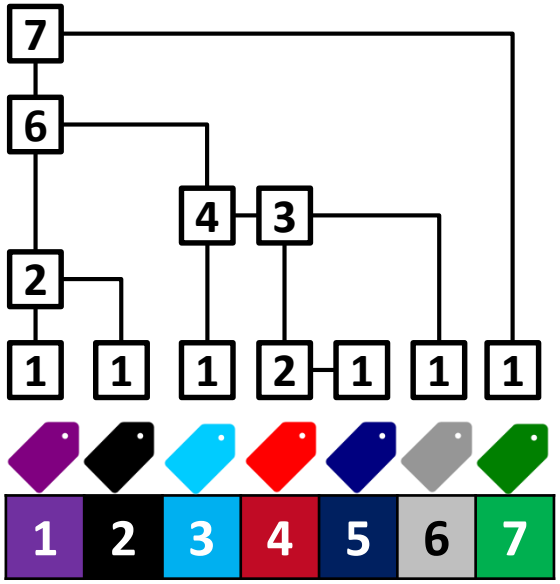

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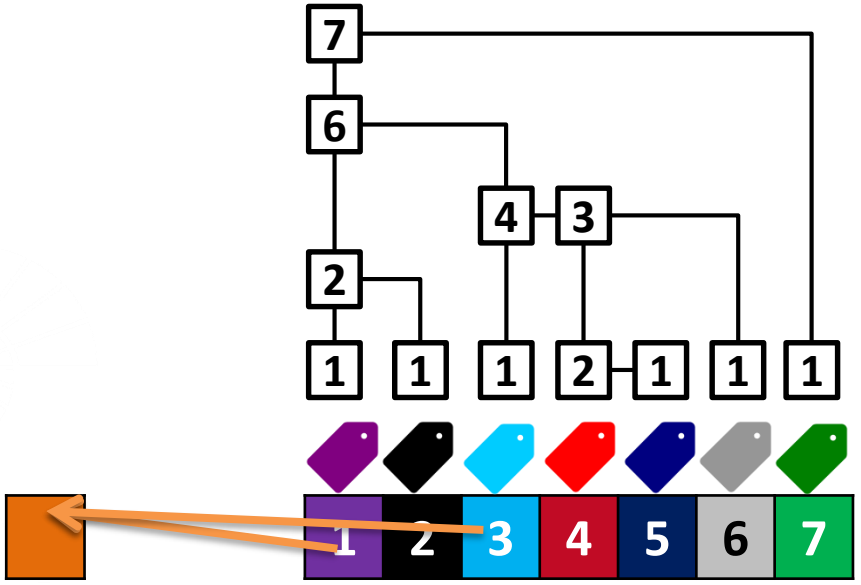

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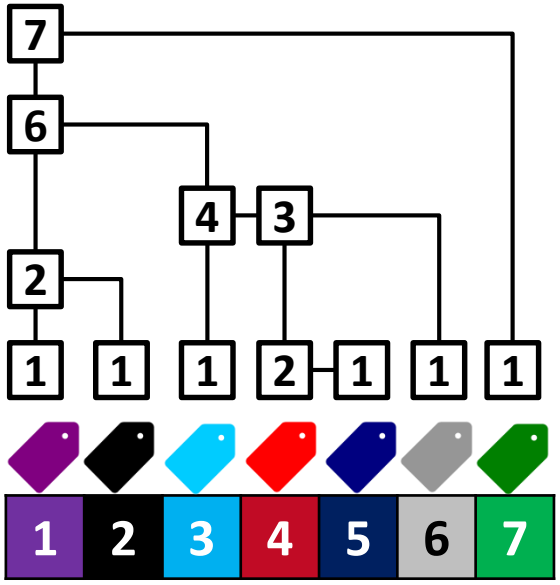

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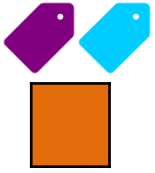

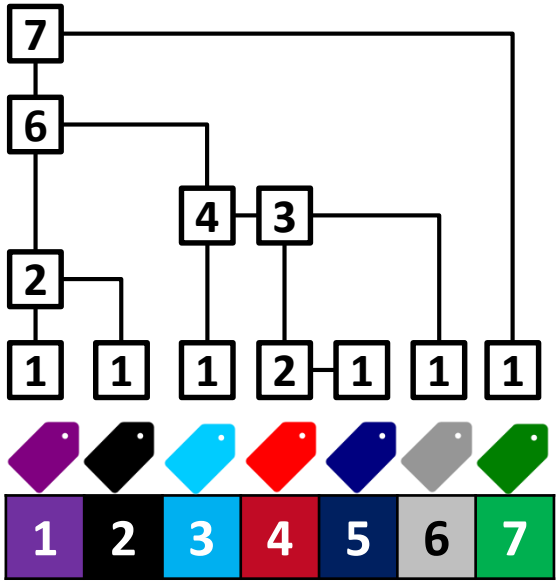

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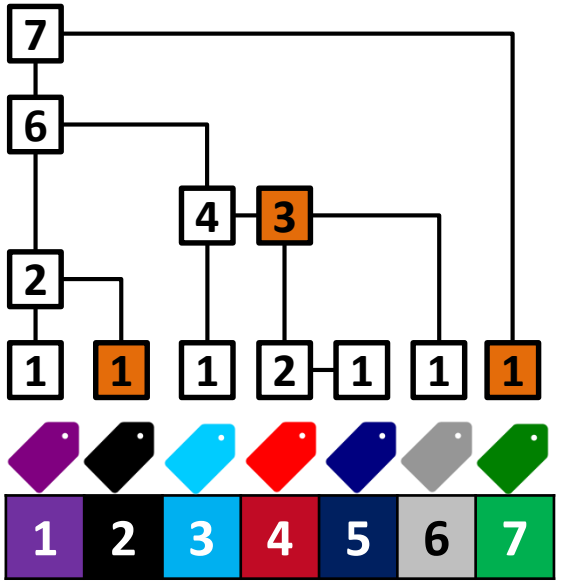

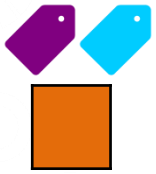

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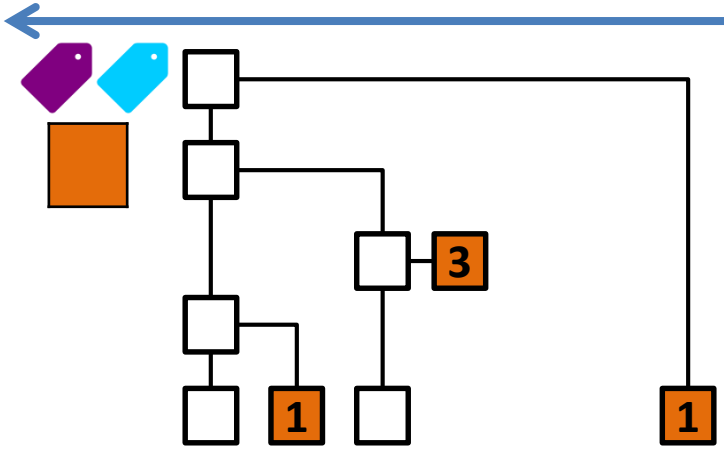

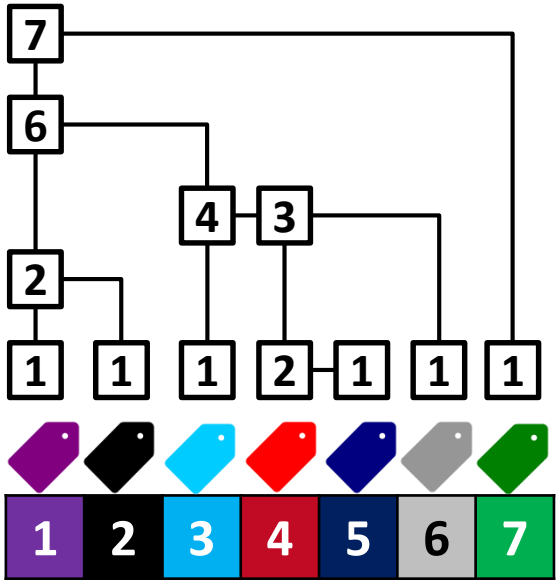

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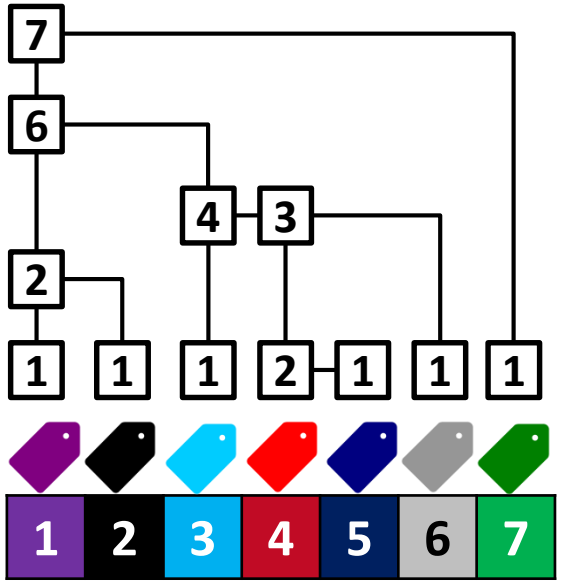

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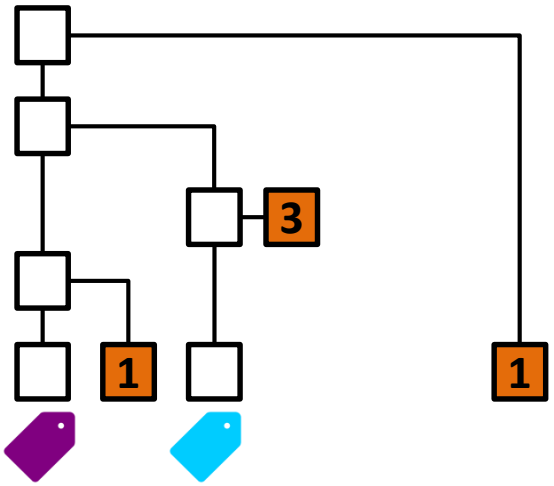

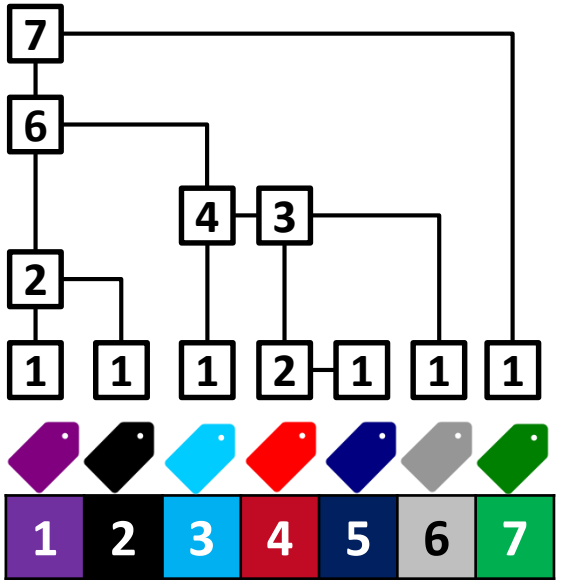

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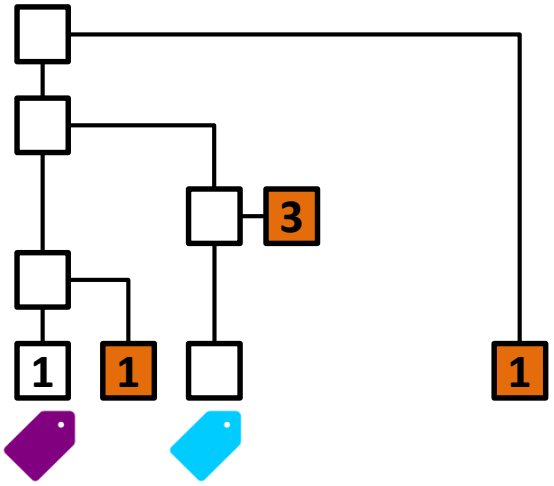

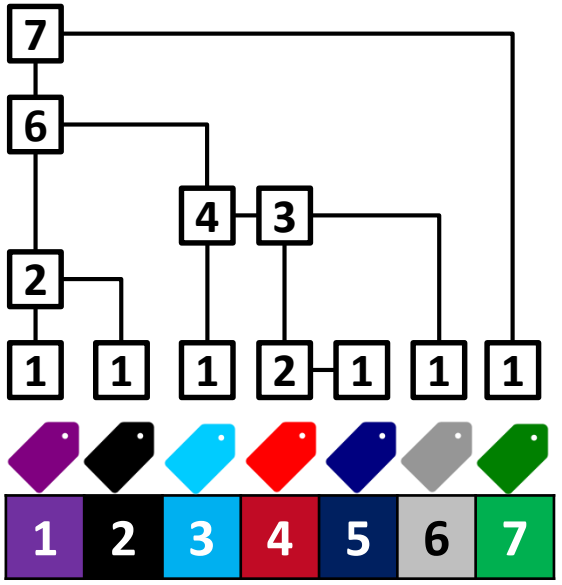

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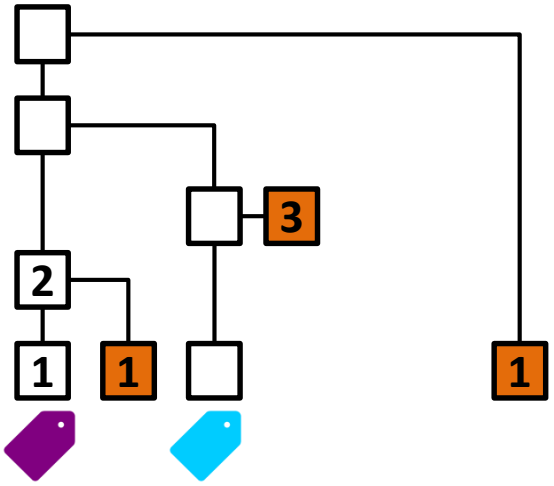

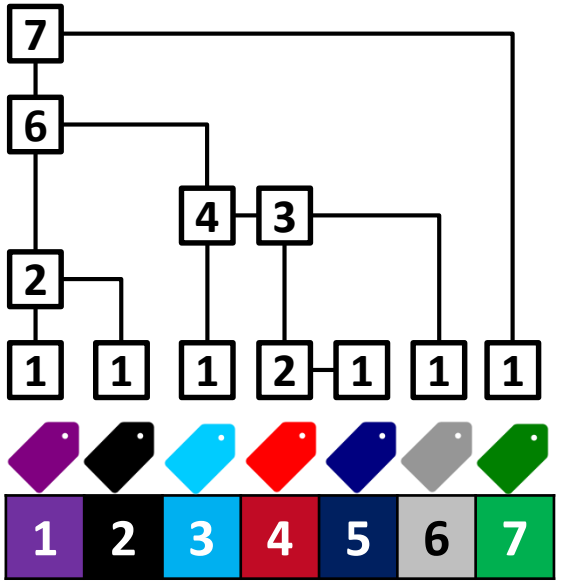

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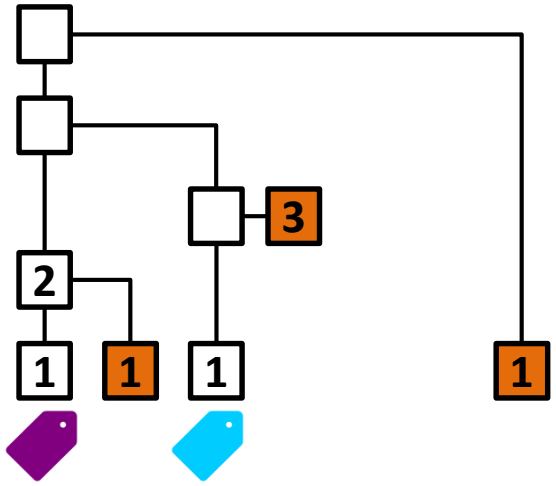

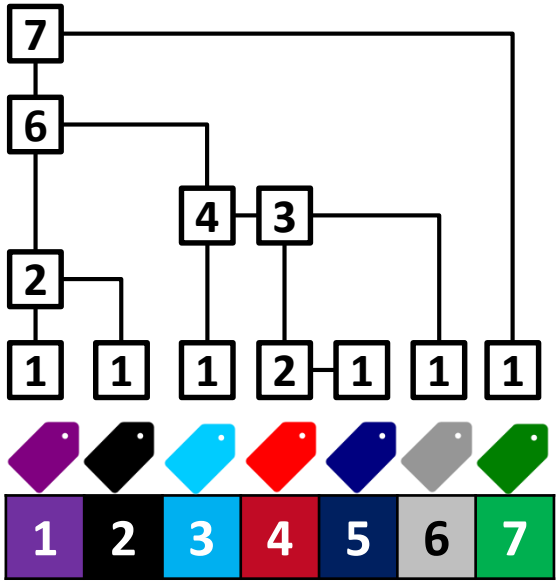

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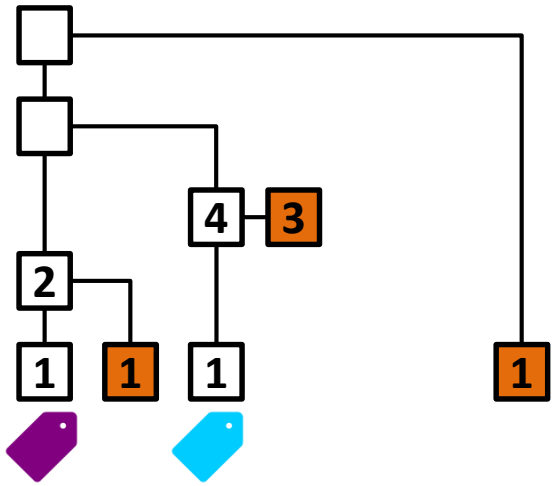

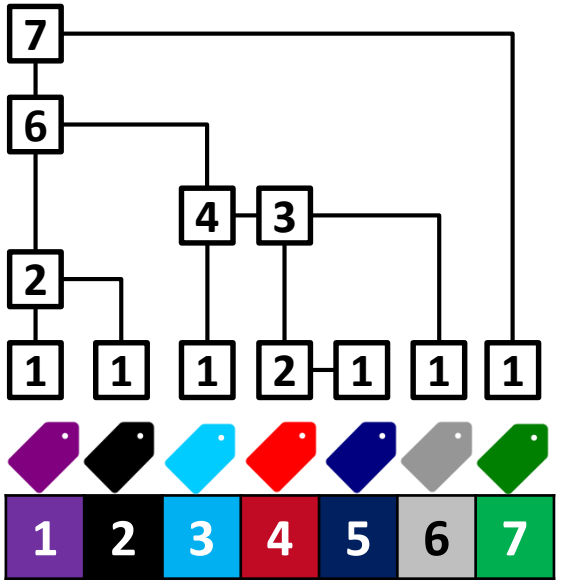

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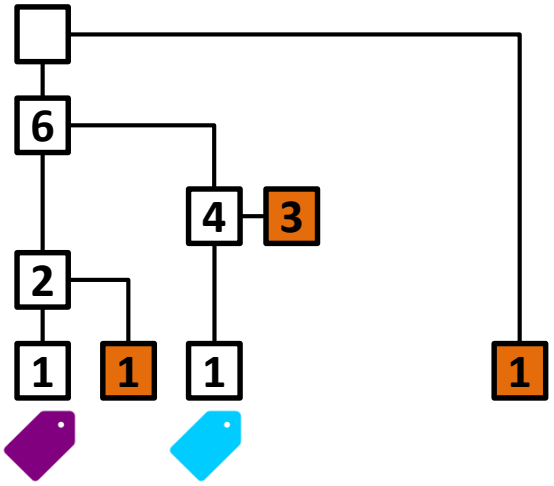

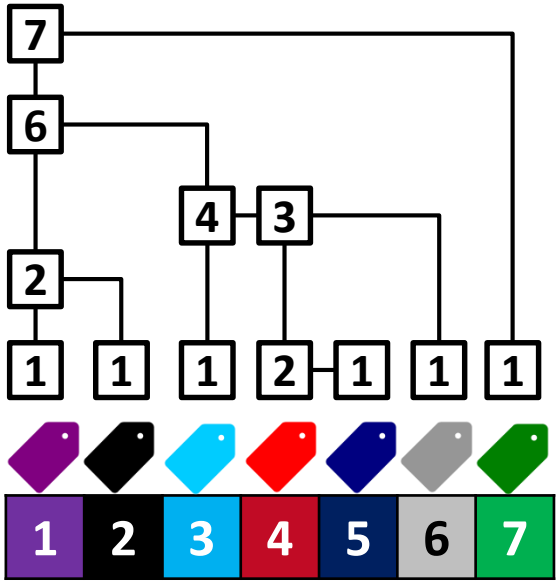

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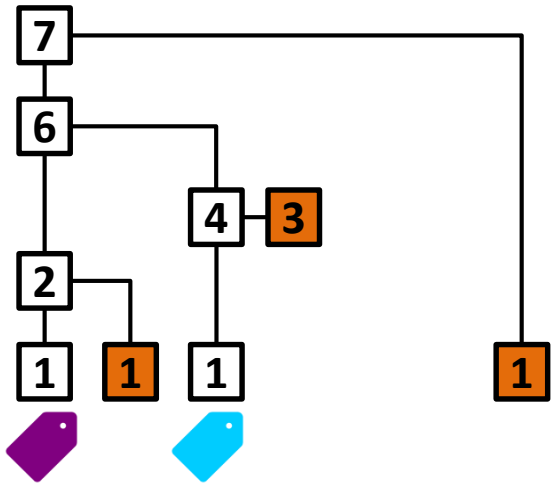

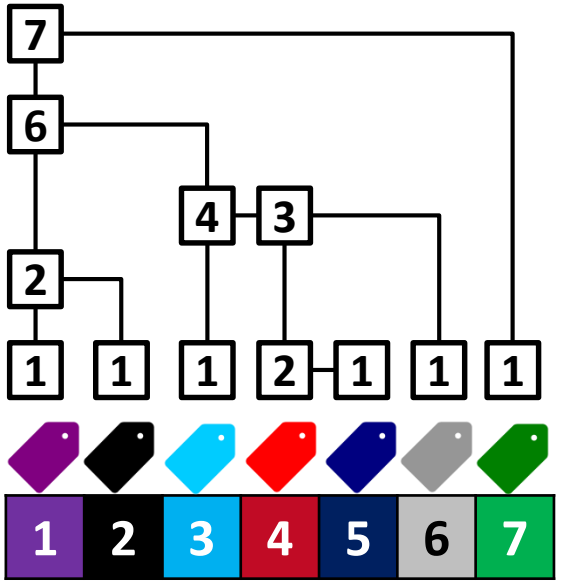

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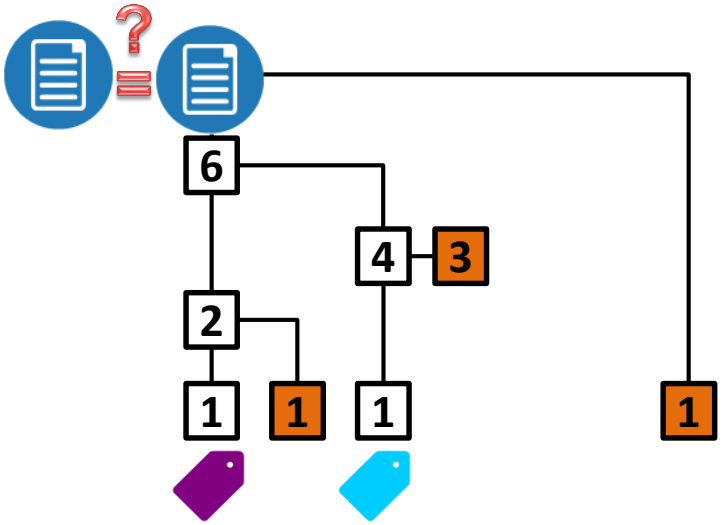

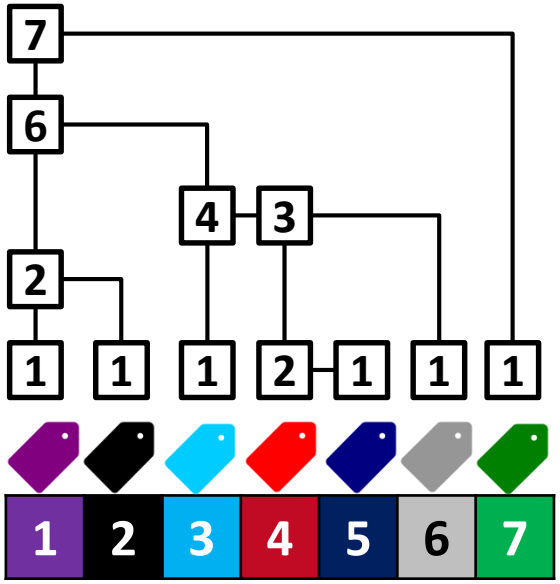

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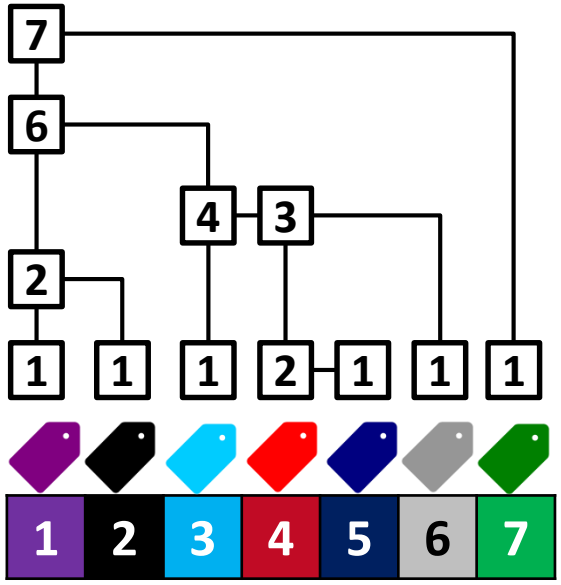

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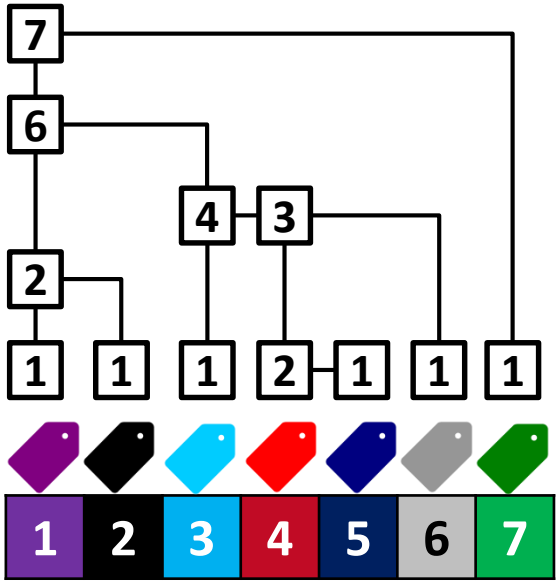

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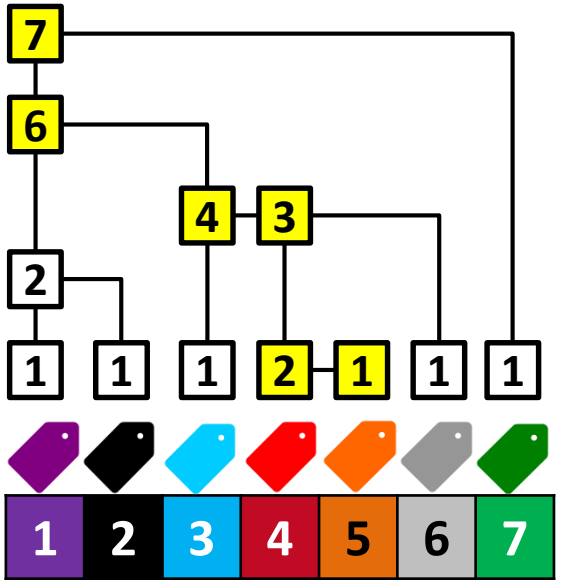

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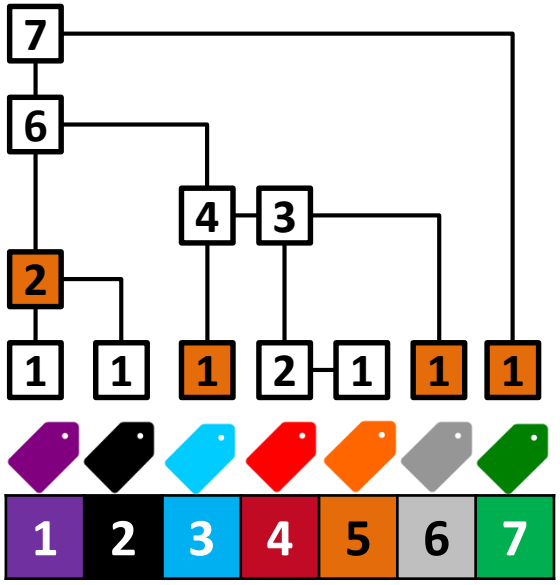

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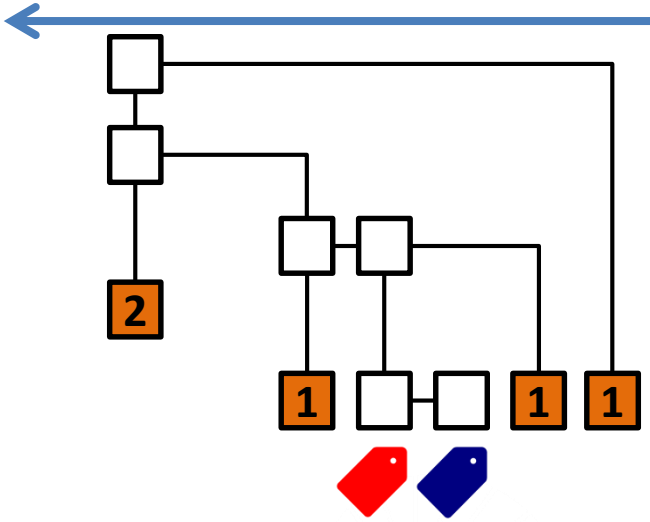

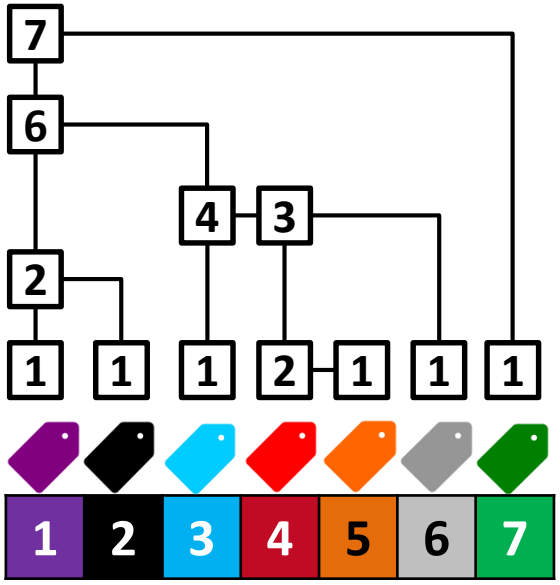

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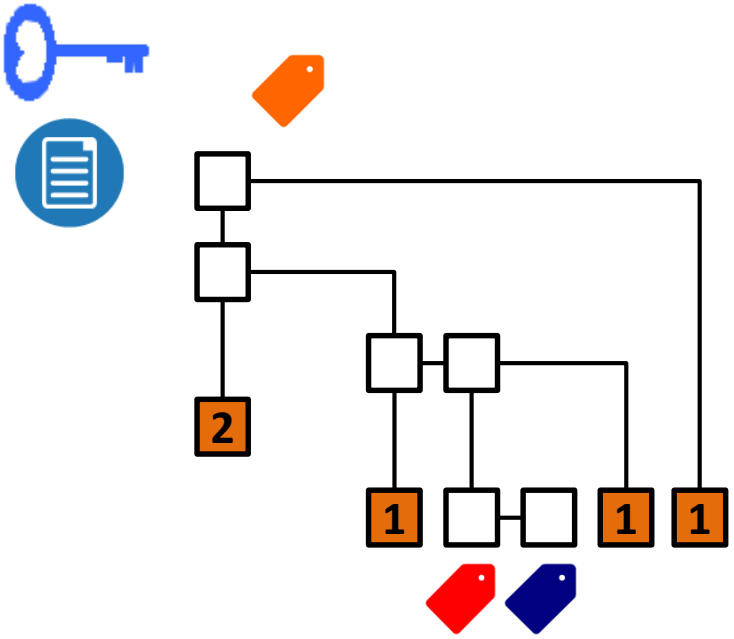

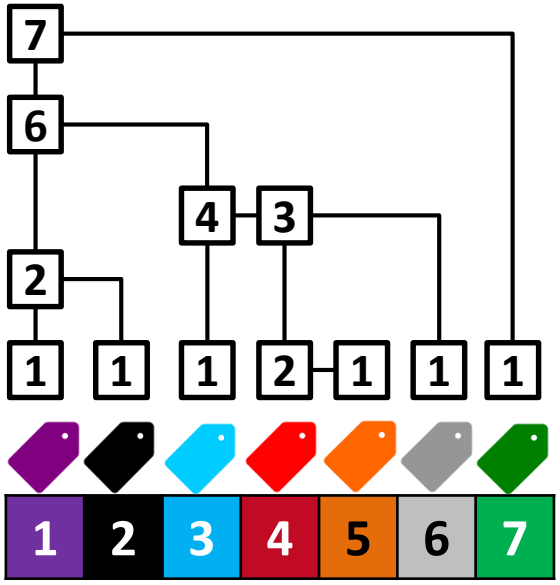

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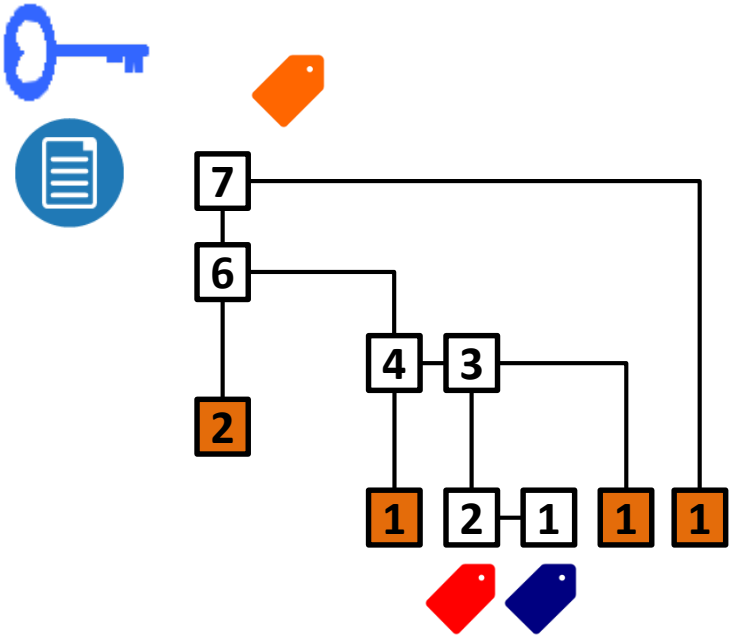

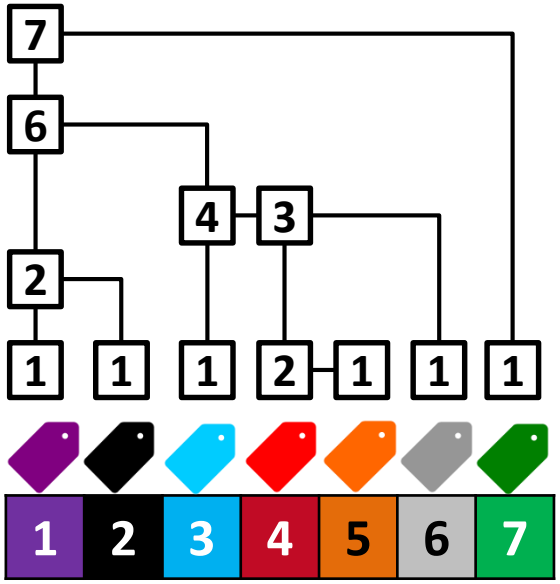

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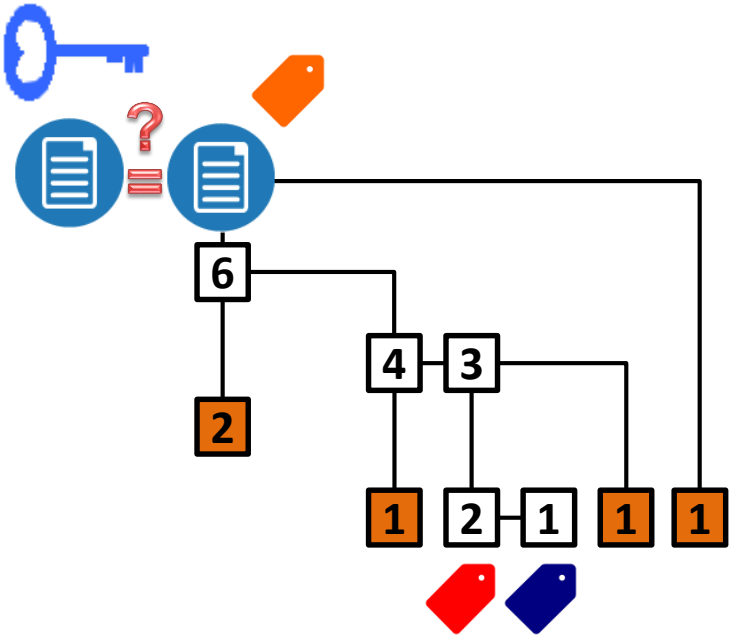

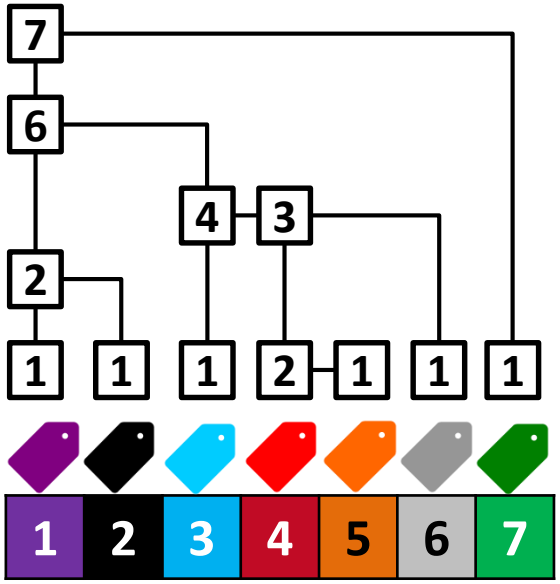

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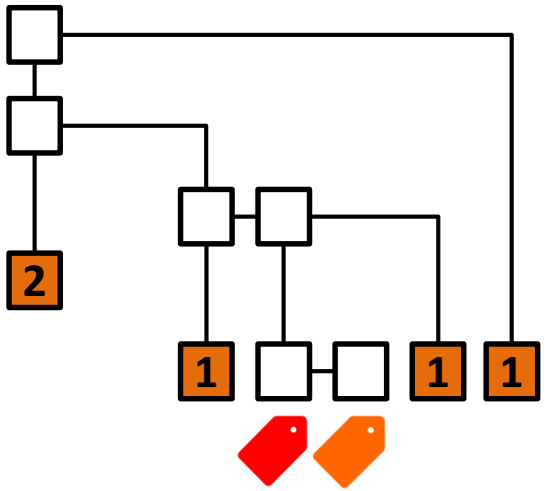

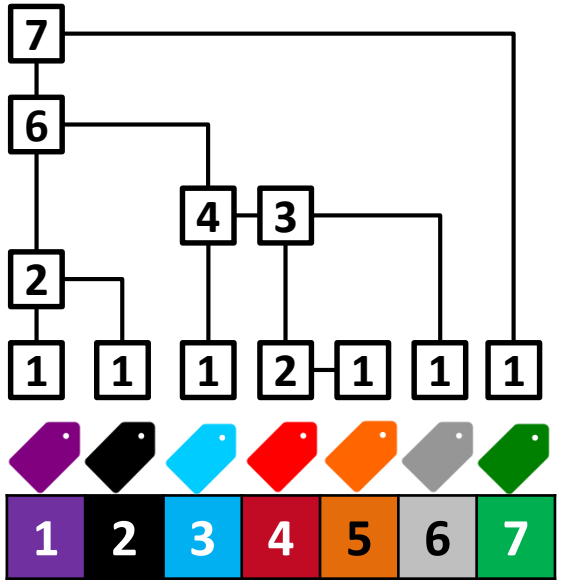

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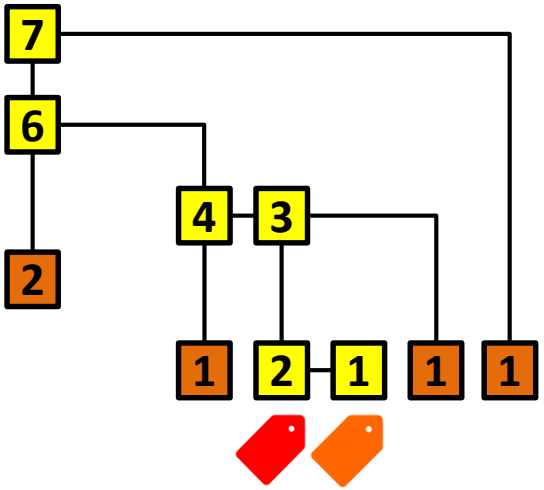

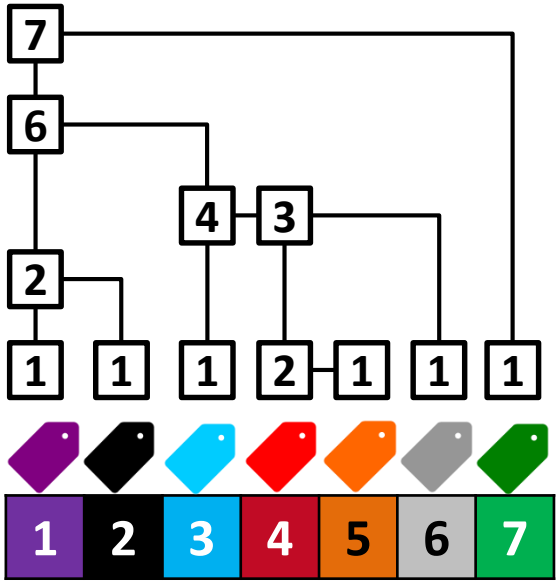

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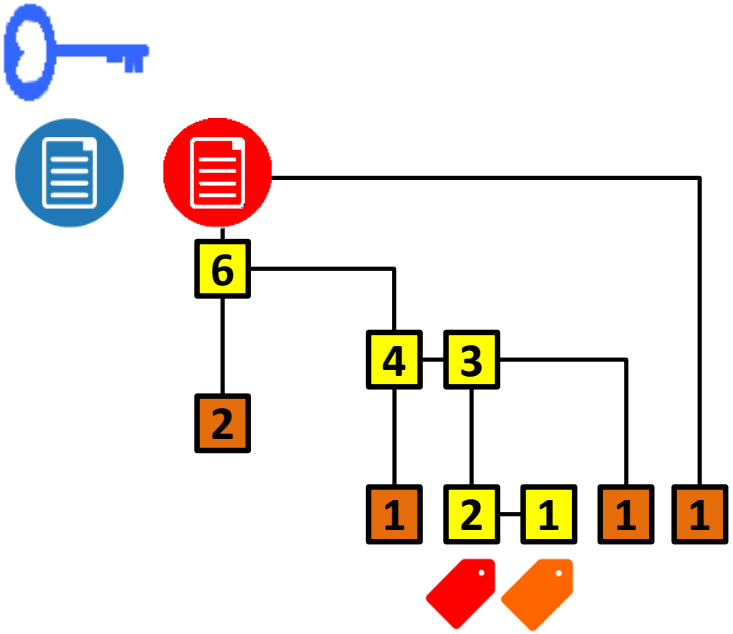

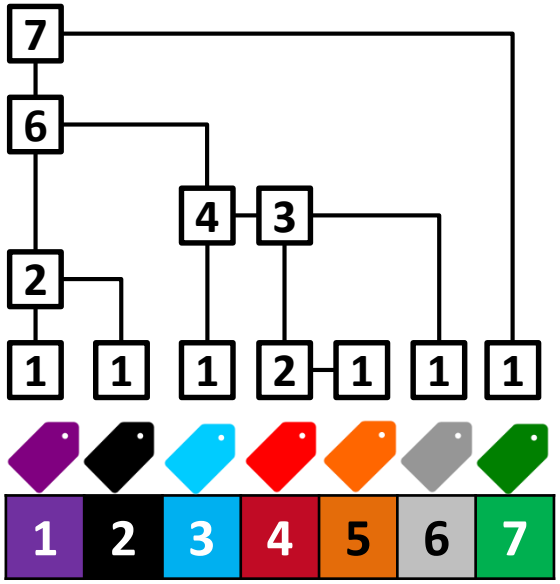

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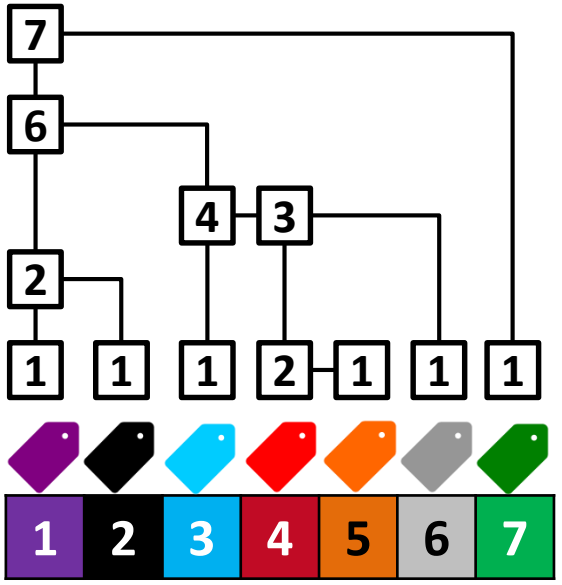

Overview

- **Secure Cloud Storage**
  - **Problems**
  - **Solutions**
  - **Summary**

Further Work

- **Distribution and Replication [EK13a]**
  - **Without increasing complexity**
- **Failure Resiliency [CKW13][CKW17]**
  - **Via error-correcting and erasure codes**
- **PDP vs. POR [EK16][EK19b]**
  - **POR uses erasure codes**
  - **PDP is more efficient**
- **What happens when the proof fails?**
  - **Official arbitration [K15]**
    - **NOT public verifiability**

READING LIST

- **Static PDP and POR**
  - Ateniese et al. ACM CCS 2007 & ACM TISSEC 2011, *Provable Data Possession*
  - Shacham and Waters. ASIACRYPT 2008 & Journal of Cryptology 2013, *Compact POR*
- **Dynamic PDP**
  - Erway, Küpçü, Papamanthou, Tamassia. ACM CCS 2009 & ACM TISSEC 2015, *Dynamic Provable Data Possession*
  - Etemad and Küpçü. ACNS 2013, *Distributed, and Replicated DPDP*
  - Esiner, Küpçü, Özkasap. ICC 2014, *FlexList*
  - Esiner, Kachkeev, Braunfeld, Küpçü, Özkasap. ACM TOS 2016 *FlexDPDP*
  - Etemad and Küpçü. ACM CSUR 2020, *Generic DPDP*
- **Dynamic POR**
  - Cash, Küpçü, Wichs. EUROCRYPT 2013 & Journal of Cryptology 2017, *PORAM*
  - Shi et al. ACM CCS 2013, *Practical DPOR*
  - Chandran et al. TCC 2014, *Locally Updatable and Locally Decodable Codes*
  - Etemad and Küpçü. ACM CCSW 2016. *Generic DPOR from PDP and DPDP.*
- **Official Arbitration**
  - Küpçü. The Computer Journal 2015, *Official Arbitration*

Conclusion

- **Cloud Storage**
  - **Can efficiently provide confidentiality and integrity of data, among multiple servers**
    - **Proof and verification times on the order of milliseconds**
    - **Proof size is a few hundred KB for a few GB file**
  - **Can handle whole file systems or version control systems**

Funding Acknowledgement

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- **Koç Sistem**
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BİLİM AKADEMİSİ

COST ACTION IC1206

DE-ID De-identification for privacy protection in multimedia content.

cost

CryptoAction

TÜRK TELEKOM

KoçSistem

TÜBA

EXCELLENCE IN SCIENCE THE ROYAL SOCIETY

Newton Fund

Entrepreneurship Timeline

- **2001: Bilkent CS 102 project**
  - **Maplab Map Simulator**
- **2004: Bilkent CS 492 Senior Project**
  - **Kaşif: Best Senior Project Award**
  - **Google Maps Beta was launched in 2005**
- **2008-2010: while still in USA**
  - **Brown University PRIME Entrepreneurship Program**
  - **Rhode Island Center for Innovation**
- **2020: TÜBİTAK BİGG awards, co-founded:**
  - **FineSci Technology Inc.**
  - **Xtinge Technology Inc.**

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