TCC 2022 Nov 8, 2022

IBE with Incompressible Master Secret and Small Identity Secrets

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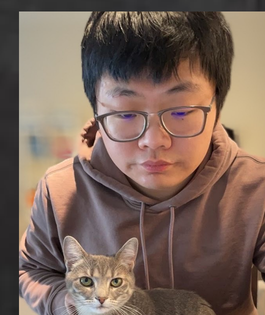

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Big-key Cryptography

Motivation: Exfiltration Attacks

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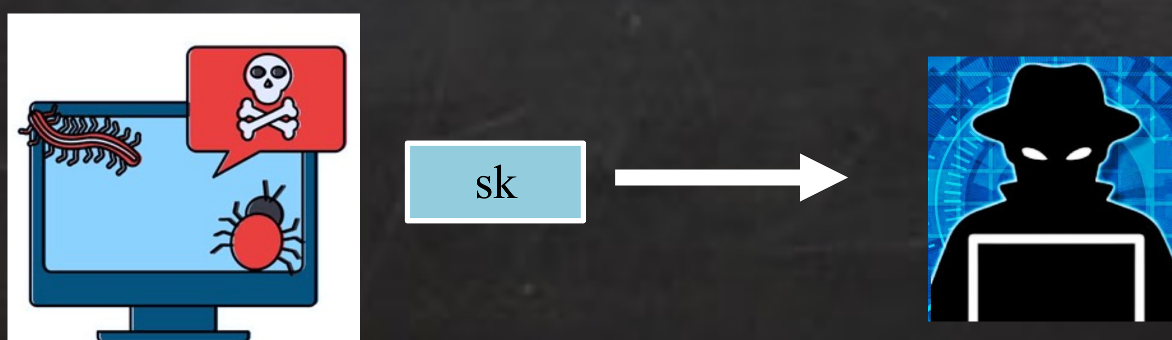
- Computers with valuable cryptographic keys prone to exfiltration attacks–giving adversary unrestricted access!



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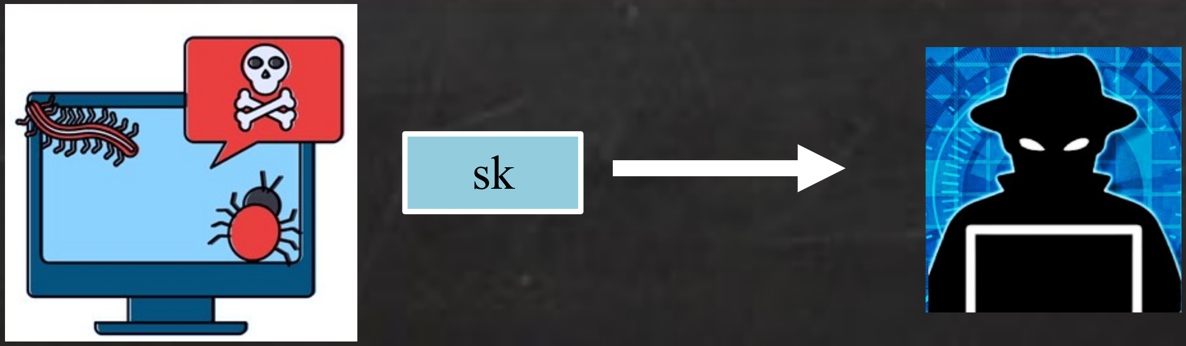
Advanced persistent threat

From Wikipedia, the free encyclopedia

An **advanced persistent threat** (**APT**) is a stealthy threat actor, typically a nation state or state-sponsored group, which gains unauthorized access to a computer network and remains undetected for an extended period.[1][2] In recent times, the term may also refer to non-state-sponsored groups conducting large-scale targeted intrusions for specific goals.[3]

Such threat actors' motivations are typically political or economic.[4] Every major business sector has recorded instances of cyberattacks by advanced actors with specific goals, whether to steal, spy, or disrupt. These targeted sectors include government, defense, financial services, legal services, industrial, telecoms, consumer goods and many more.[5][6][7] Some groups utilize traditional espionage vectors, including social engineering, human intelligence and infiltration to gain access to a physical location to enable network attacks. The purpose of these attacks is to install custom malware (malicious software).[8]



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- Solution: Make the secret key BIG (say ~ 1 TB)!

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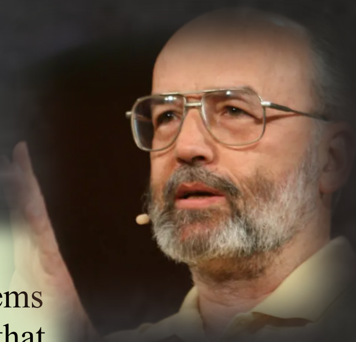
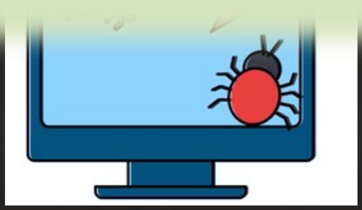


Adi Shamir
@RSA 2013

“We have to think in a totally different way about how we are going to protect computer systems assuming there are APTs inside already which cannot be detected. Is everything lost? I claim that not: there are many things that you can do, because the APT is basically going to have a very, very narrow pipeline to the outside world. . . . I would like, for example, all the small data to become big data, just in terms of size. I want that the secret of the Coco-Cola company to be kept not in a tiny file of one kilobyte, which can be exfiltrated easily by an APT · · · . I want that file to be a terabyte, which cannot be [easily] exfiltrated.”



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Big-key Cryptography

Bounded Retrieval Model

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- Big-key Cryptosystems [Dzi06, DLW06, CDD+07, ADW09, ADN+10, BKR16, MW20] (in bounded-retrieval model (BRM)):

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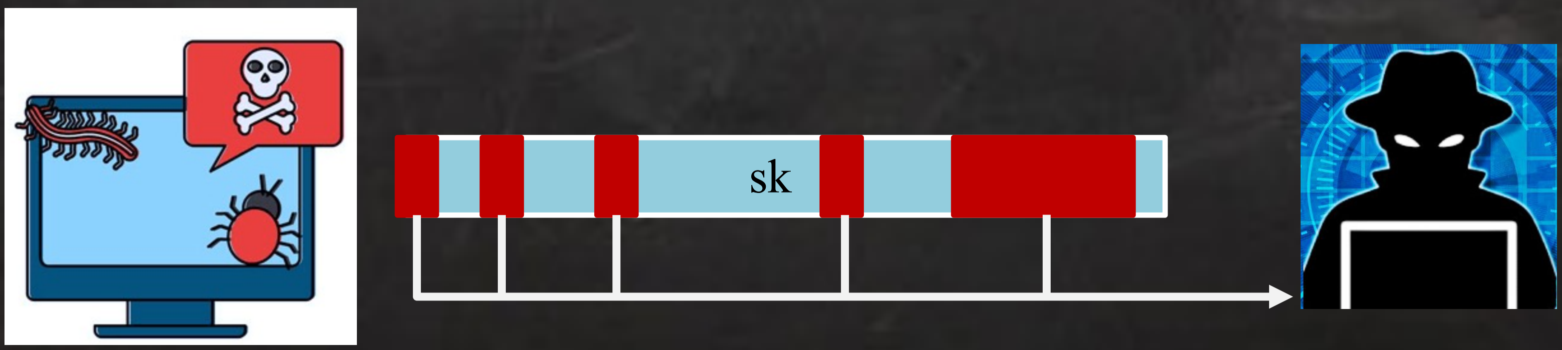

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Big-key primitives: symmetric key encryption [BKR16], public-key encryption [ADN+10, MW20], authenticated key agreement [Dzi06, CDD+07, ADW09].

Big-key (Public-key) Encryption

The Model

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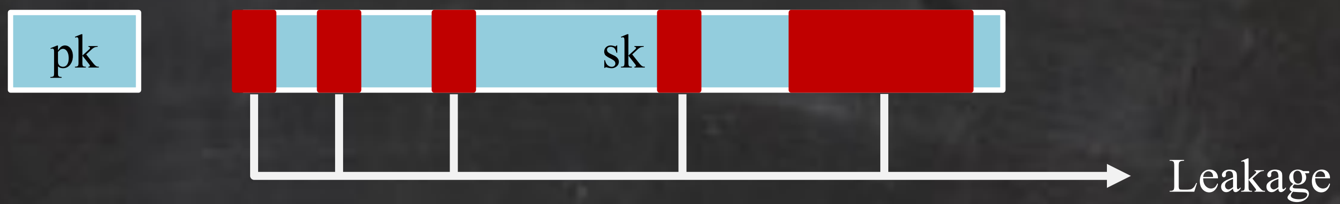
- Public-key setup: small public key, large secret key (prone to exfiltration).



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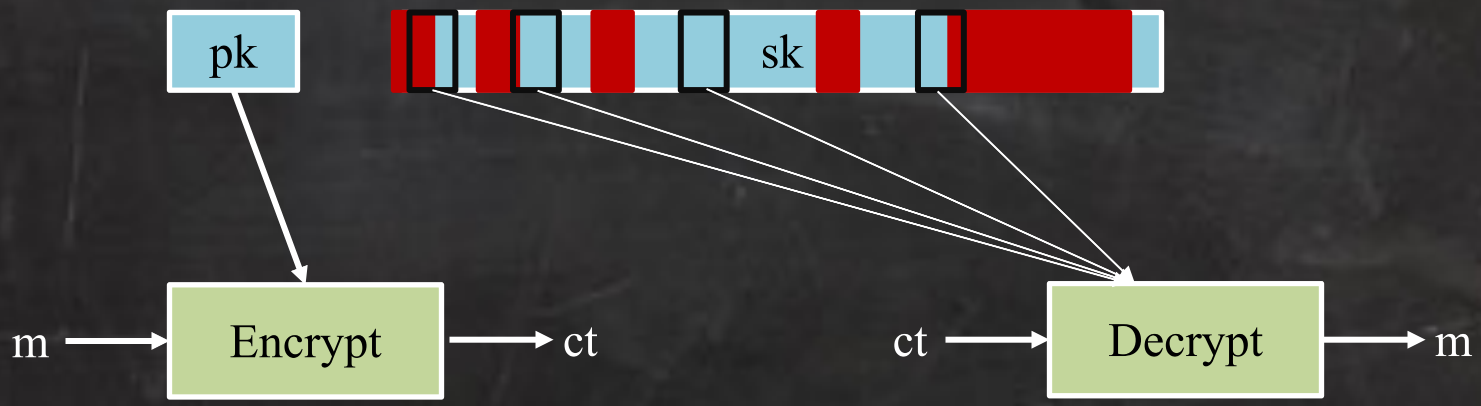

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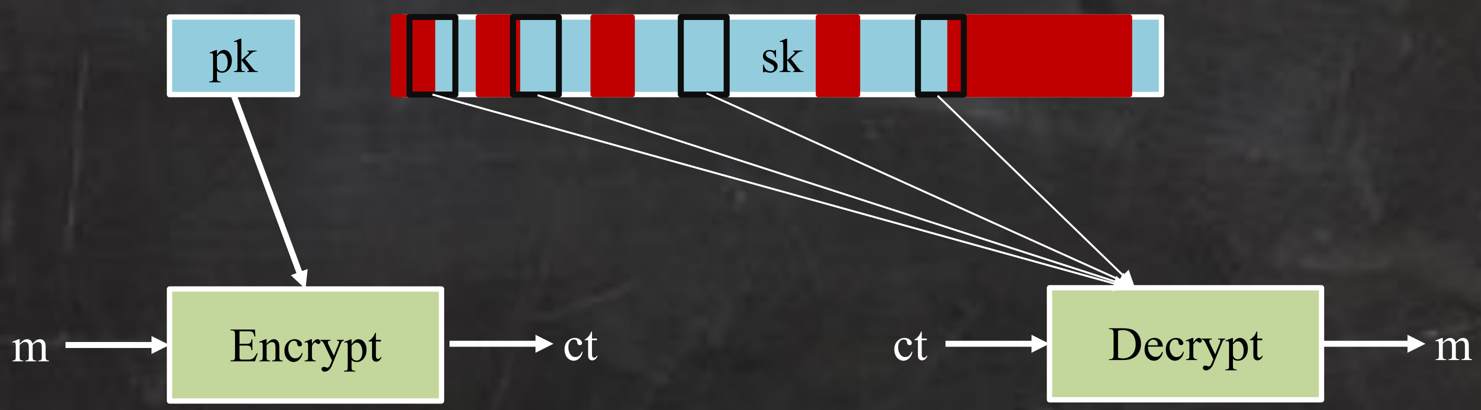
Security: semantic security of fresh ciphertexts generated after arbitrary leakage on sk is given to the adversary.



Big-key (Public-key) Encryption

Caveats of The Model

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User must carry entire large secret key on all its devices.
(since parts of sk needed to decrypt are unknown a priori)

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1. Leads to wastage of limited storage space on small mobile devices.

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User must carry entire large secret key on all its devices.

1. Leads to wastage of limited storage space on small mobile devices.

2. Replication of the large secret makes use more susceptible to leakage (e.g., the loss of a mobile device will leak whole of sk!)

Our Solution: Big-key IBE

Our IBE-based Model

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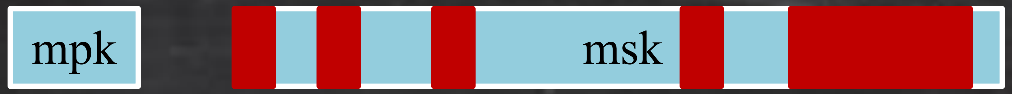
Our IBE-based Model

Use the advantages of identity-based encryption-

- Setup: generates master public and secret keys (mpk,msk).
  (Big key setup: msk is now a big-key and prone to exfiltration).



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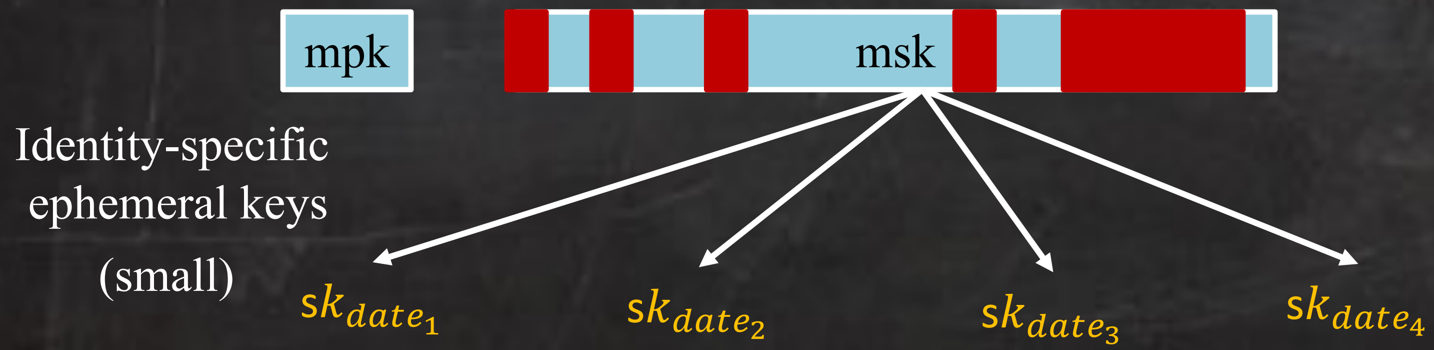
- Decryption uses short identity-specific ephemeral keys sk_{id}.



Big-key IBE

Challenges in Defining Security

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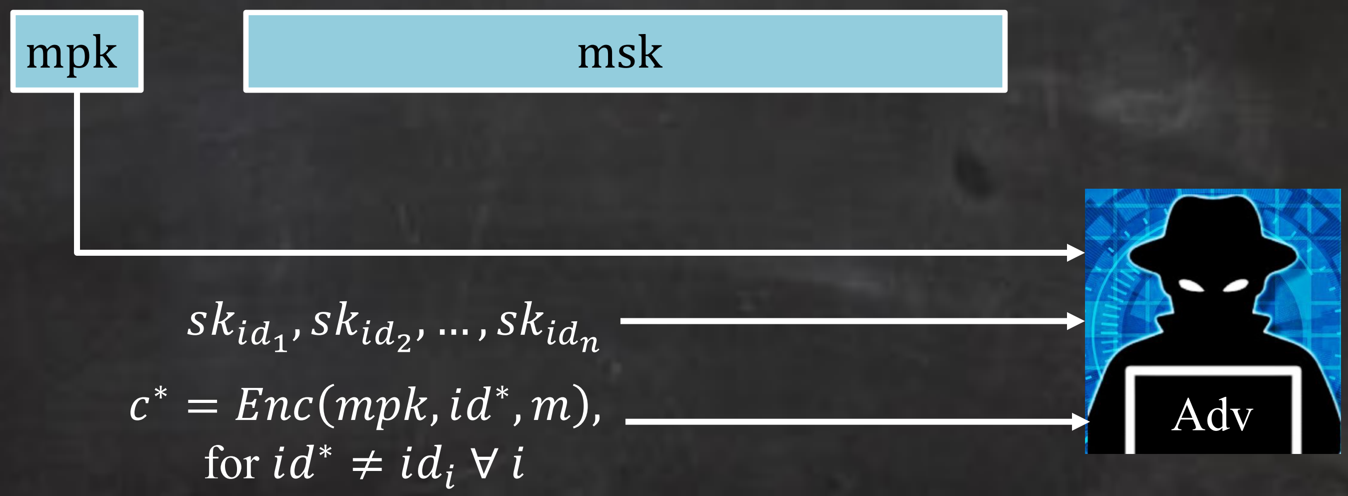
- Standard IBE security: Adv gets polynomial number of sk_{id}'s, challenge ciphertext $c^* = Enc(\text{mpk}, id^*, m)$ hides m.



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mpk　　msk

$sk_{id_1}, sk_{id_2}, \ldots, sk_{id_n}$

$c^* = Enc(mpk, id^*, m)$,
for $id^* \neq id_i \; \forall \; i$

Selective security: id^* given by Adv before seeing mpk.
Full security: id^* given by Adv after seeing mpk.

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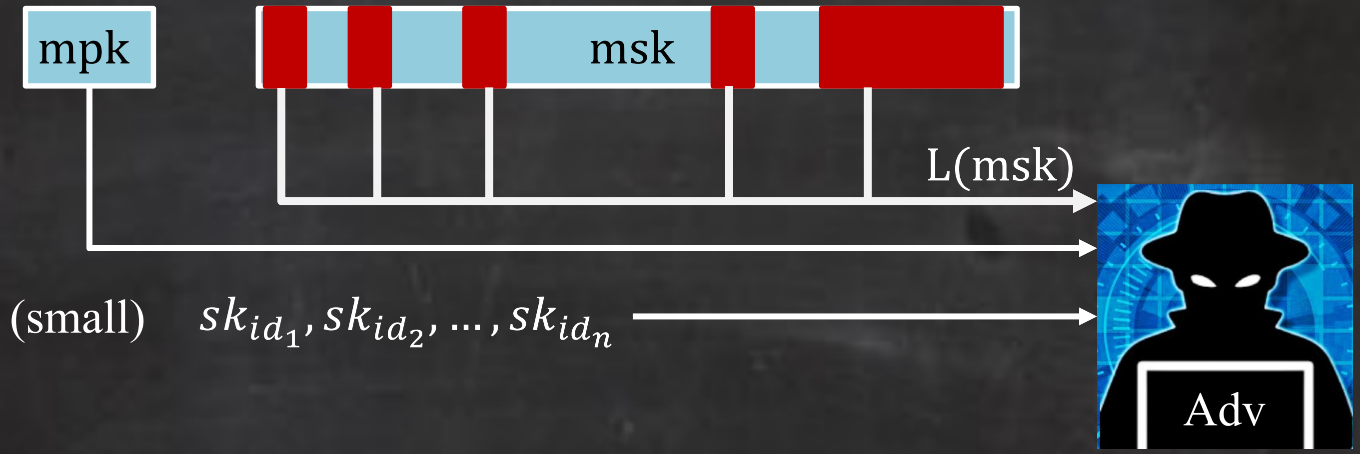
Challenges in Defining Security

- Big-key IBE security: Adv gets L(msk) in addition to polynomial number of sk_{id}'s.



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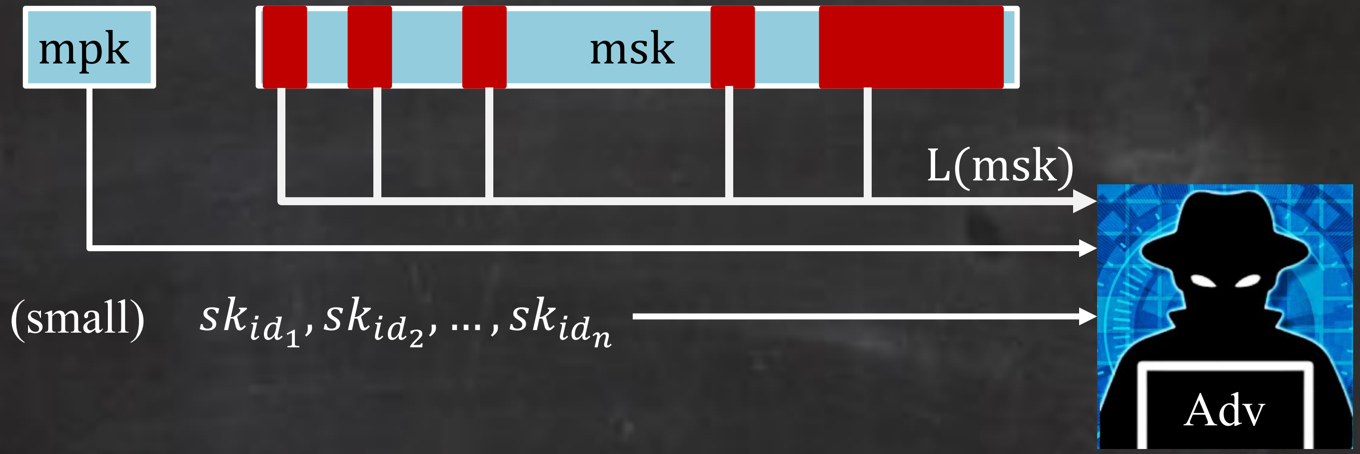

Key Challenge in defining security: Adv can get the challenge sk_{id^*} directly through L(msk) (since the output length of L is large)—breaks security.

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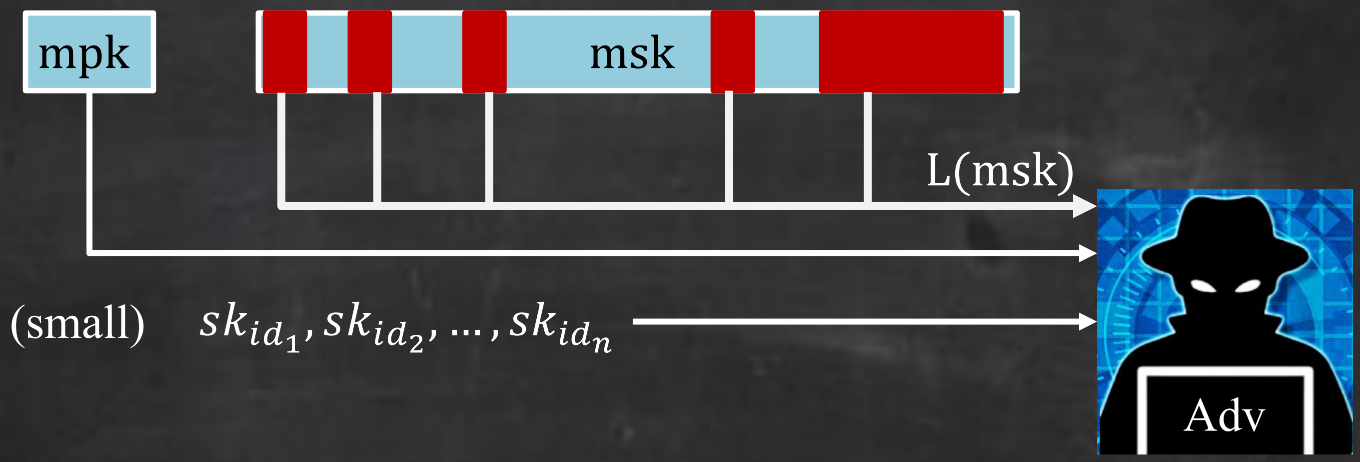

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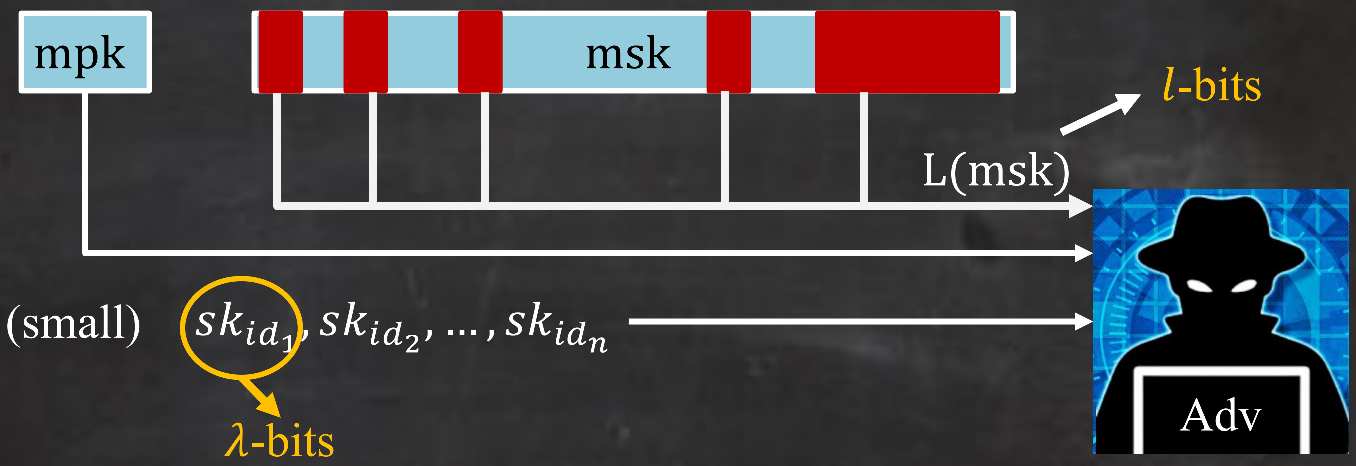
Prior Leakage-resilient IBEs [ADN+10, CDRW10,LRW11,HLWW13,CZLC16,NY19] —had large sk_{id}'s and msk is either large or allows no leakage.

Big-key IBE

Towards Defining Security

- Big-key IBE security: Adv gets L(msk) in addition to polynomial number of sk_{id}'s.



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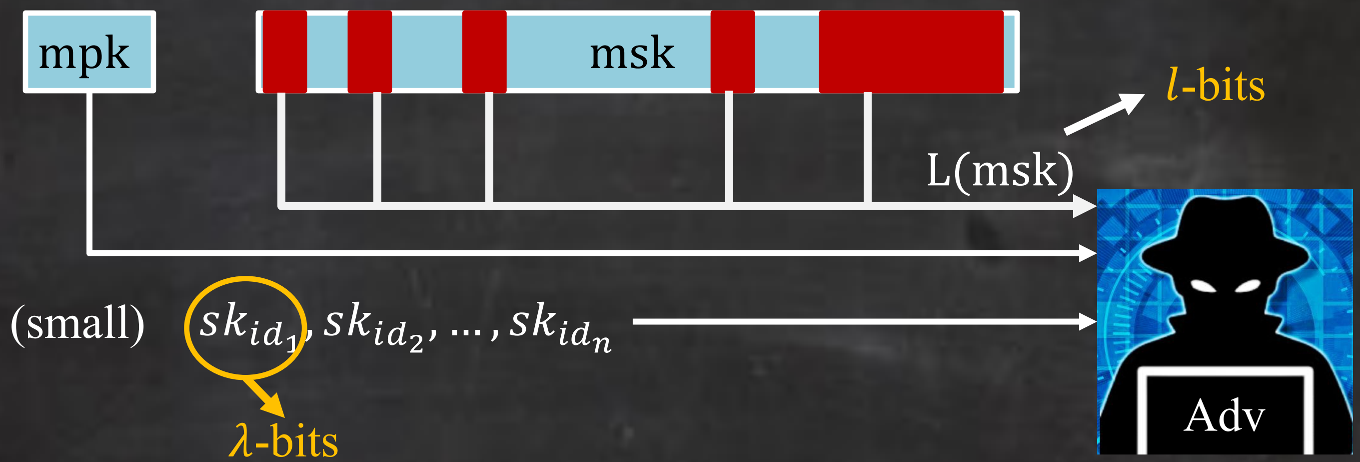

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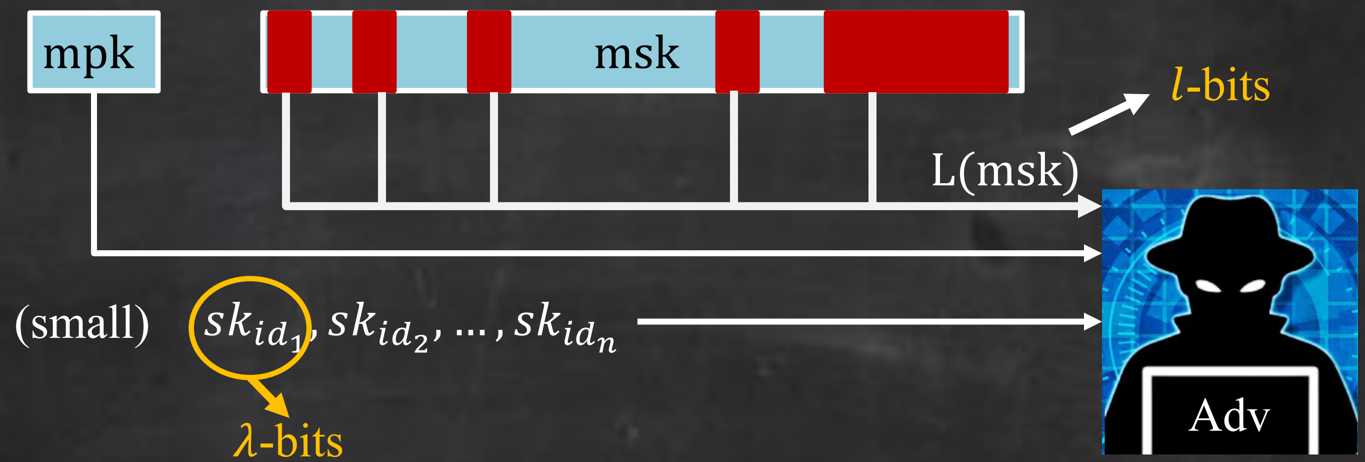

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  Particularly, given l-bit leakage, we want Adv to not break security for $\geq l + 1$ identities.

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Our Security Model

$J = \{id_1, \ldots, id_{l+1}\}$

Big-key IBE

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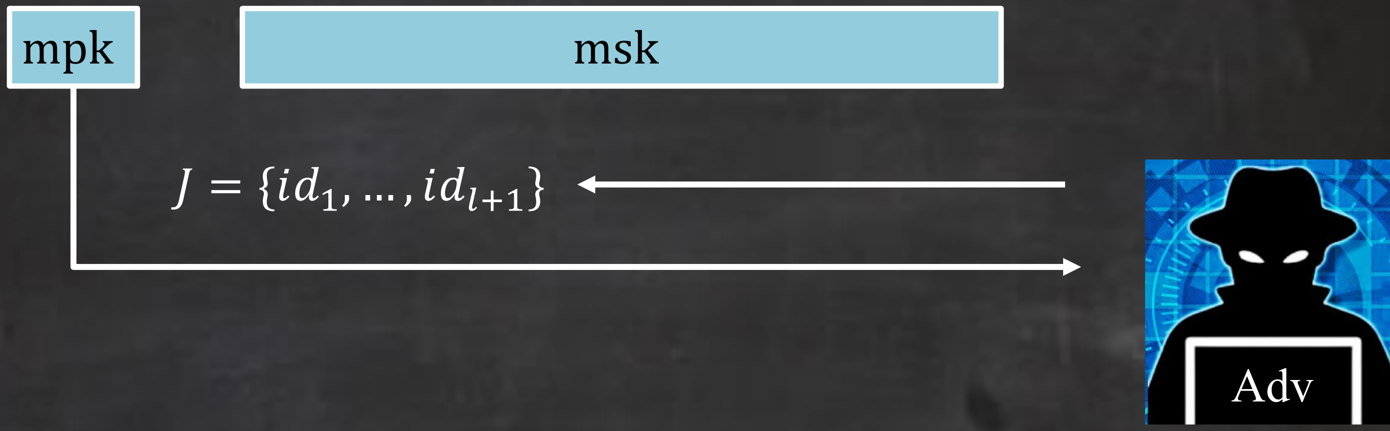

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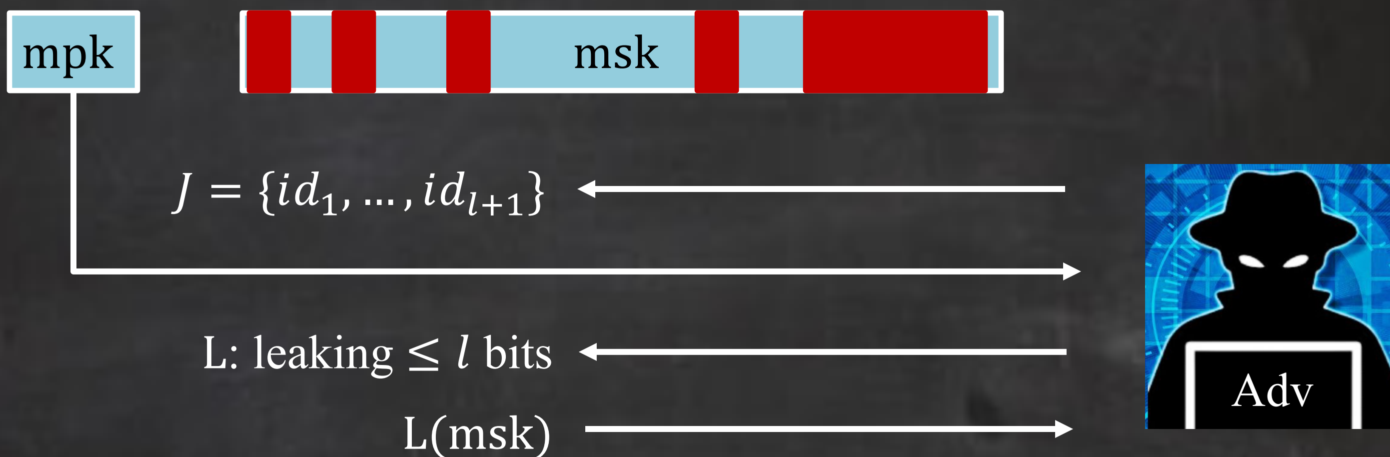

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L: leaking $\leq l$ bits

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Exp^{id} (for $id \in J$):

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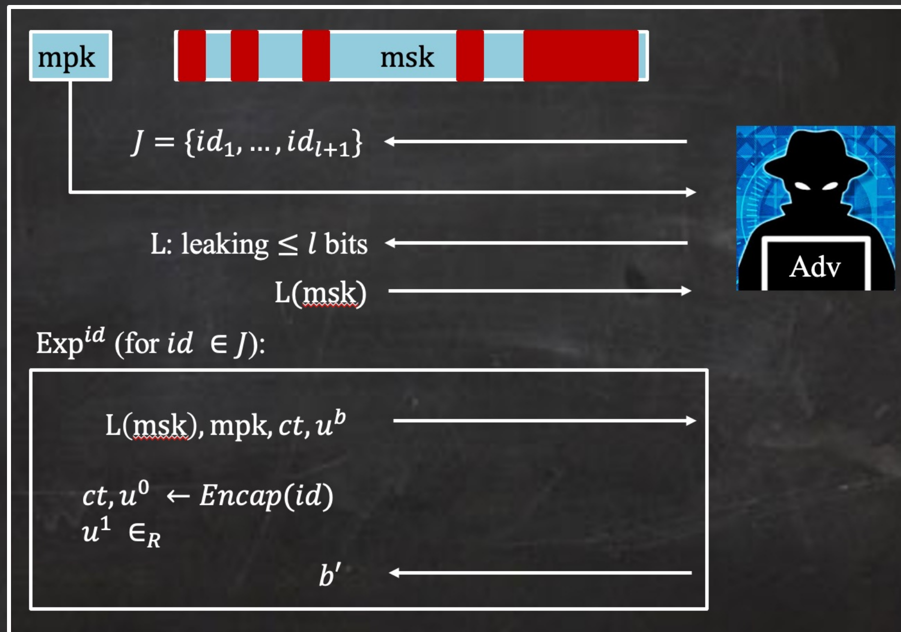

Selective Security:

$$\Pr[\forall\, id \in J, |\Pr[b' = b] - 1/2| \geq \varepsilon]$$ is negligible.

Big-key IBE

Construction Overview

Big-key IBE

Construction Overview

Big-key
Pseudo-entropy
Function

Big-key IBE

Construction Overview

Big-key Pseudo-entropy Function

+

Leakage-resilient Encryption [HLWW13]
Reusable 2-round MPC [BL20]

Big-key IBE with large mpk

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Big-key Pseudo-entropy Function

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Laconic OT [CDG+17]

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*Security relies on hardness of standard assumptions on groups with bilinear pairing

Open Problems

- How to make the construction black-box in the underlying primitives?
- How to make the big-keys useful, a.k.a. catalytic?
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THANK YOU

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