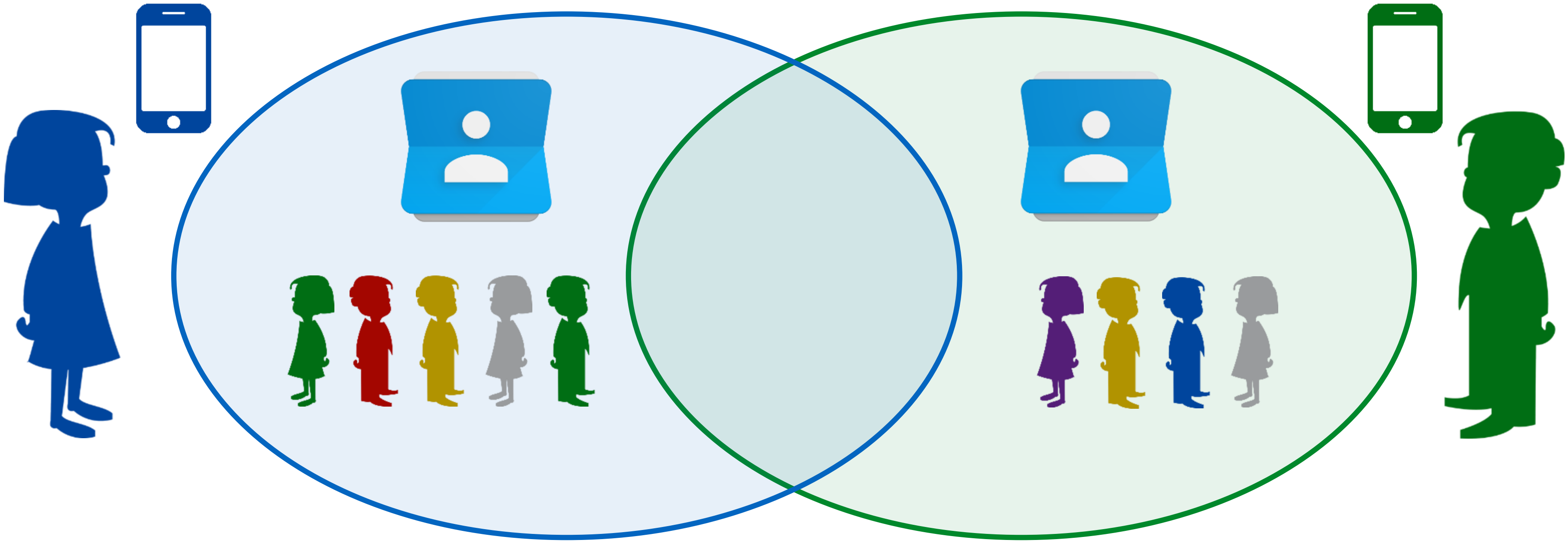
Private Set Intersection for Unequal Set Sizes with Mobile Applications

Ágnes Kiss (TU Darmstadt)

Jian Liu (Aalto University)
Thomas Schneider (TU Darmstadt)
N. Asokan (Aalto University)
Benny Pinkas (Bar-Ilan University)

Private Set Intersection (PSI)



$$N_A \approx N_B$$

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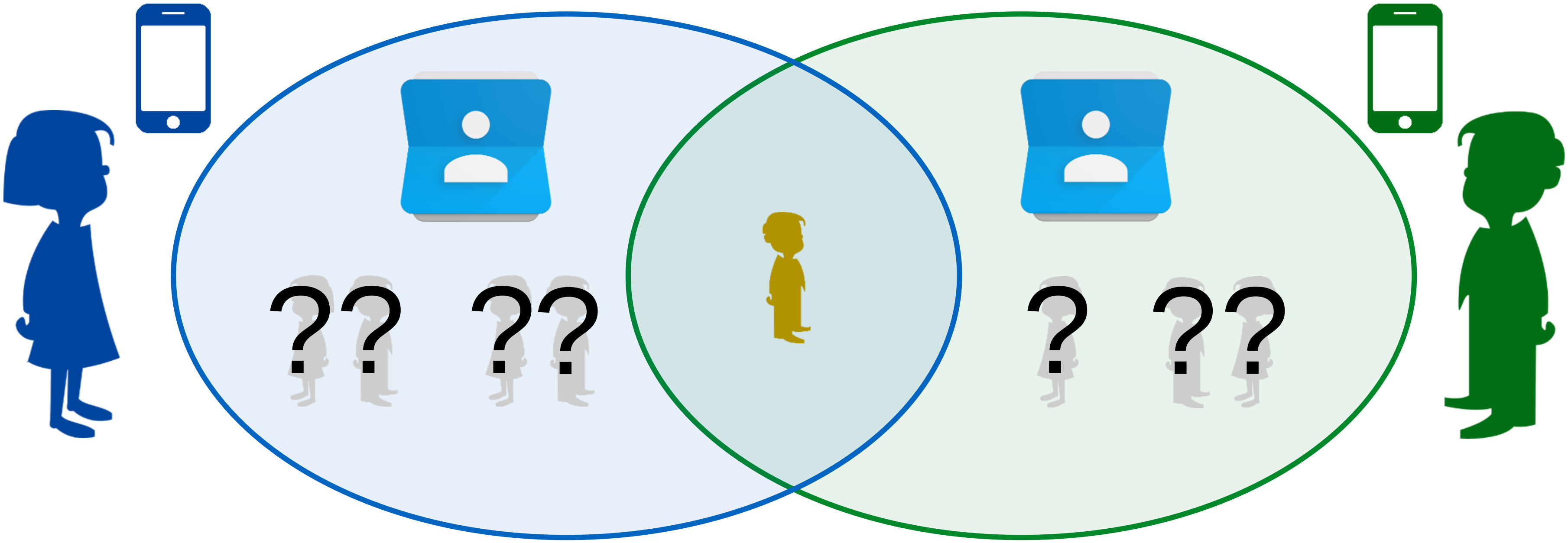

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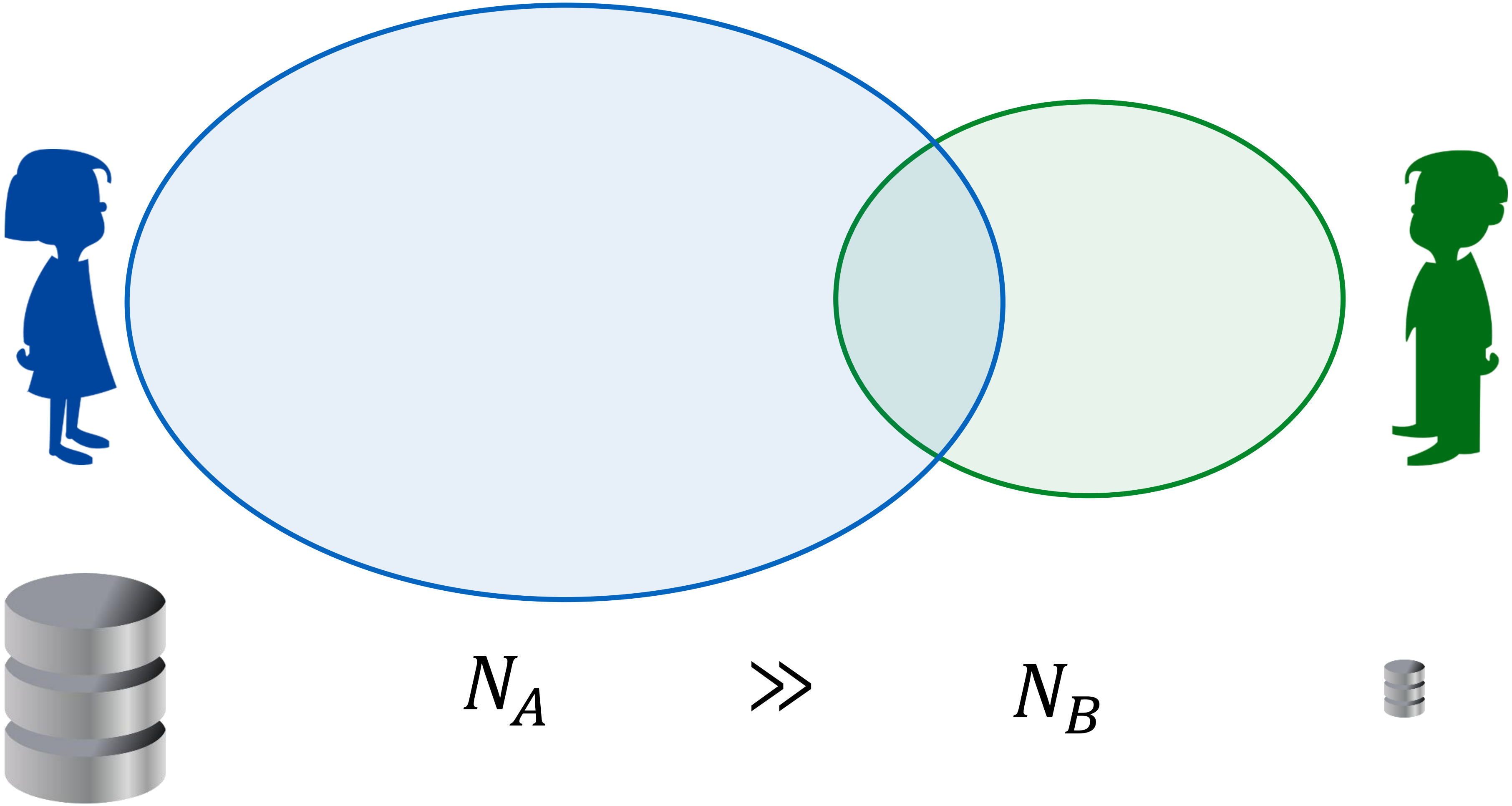
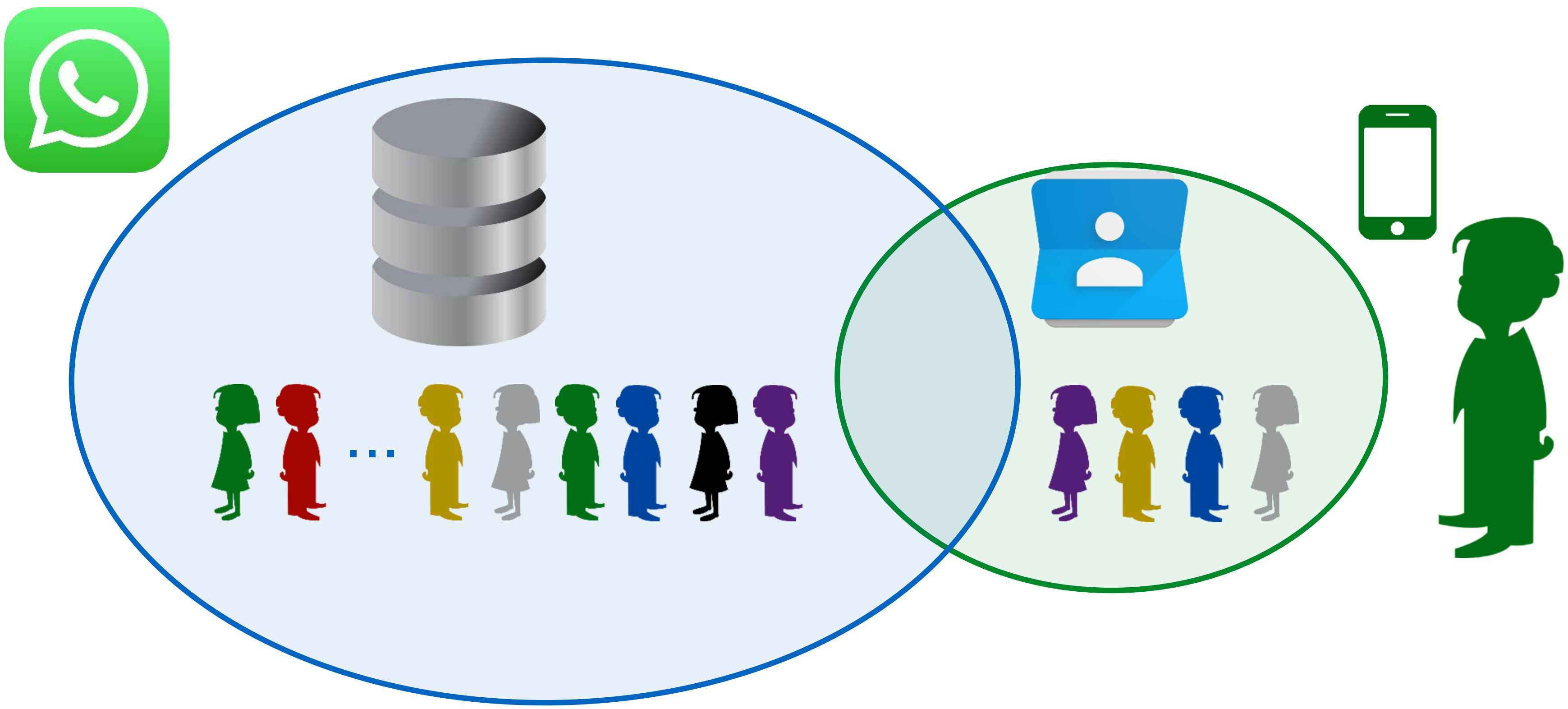
PSI with Unequal Set Sizes



PSI with Unequal Set Sizes – Mobile Messaging Service



$$N_A \gg N_B$$

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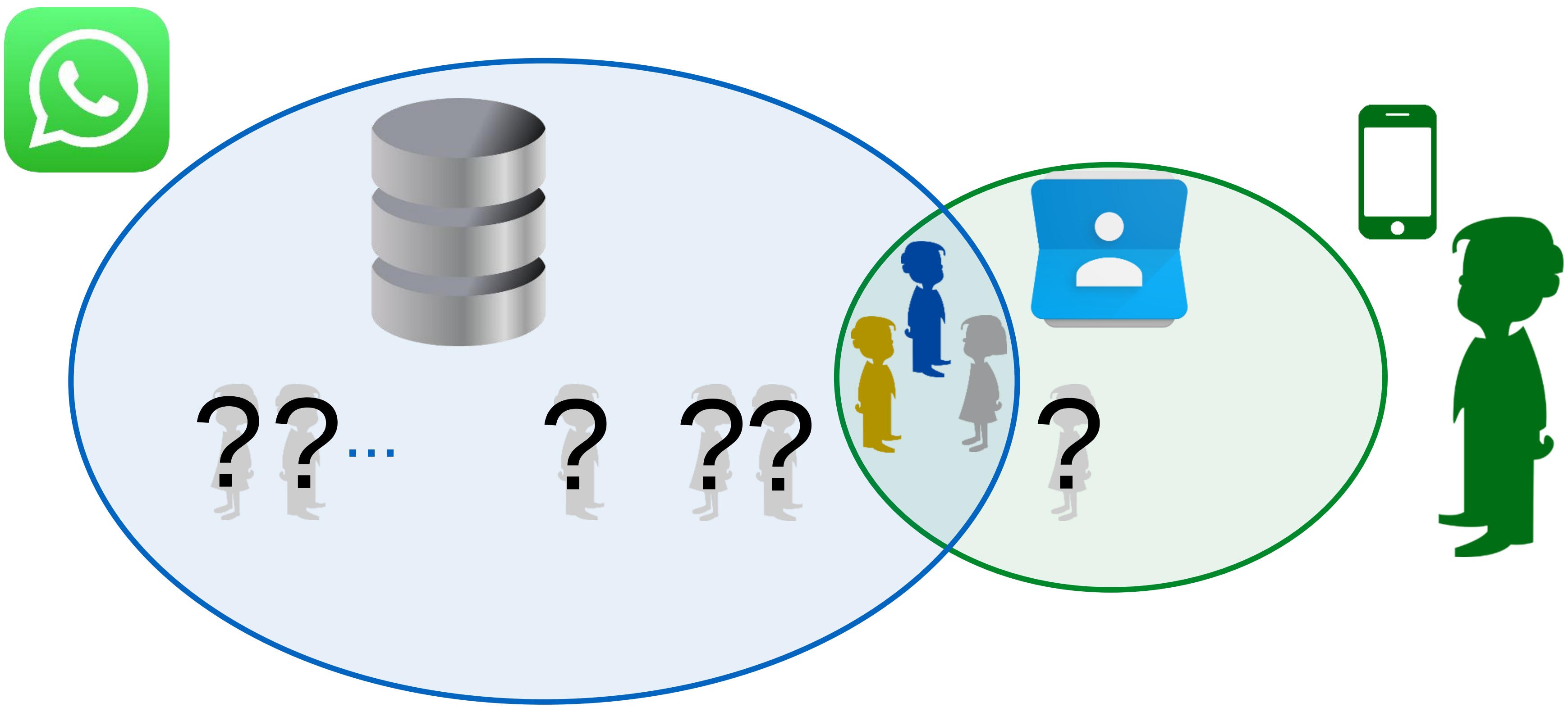

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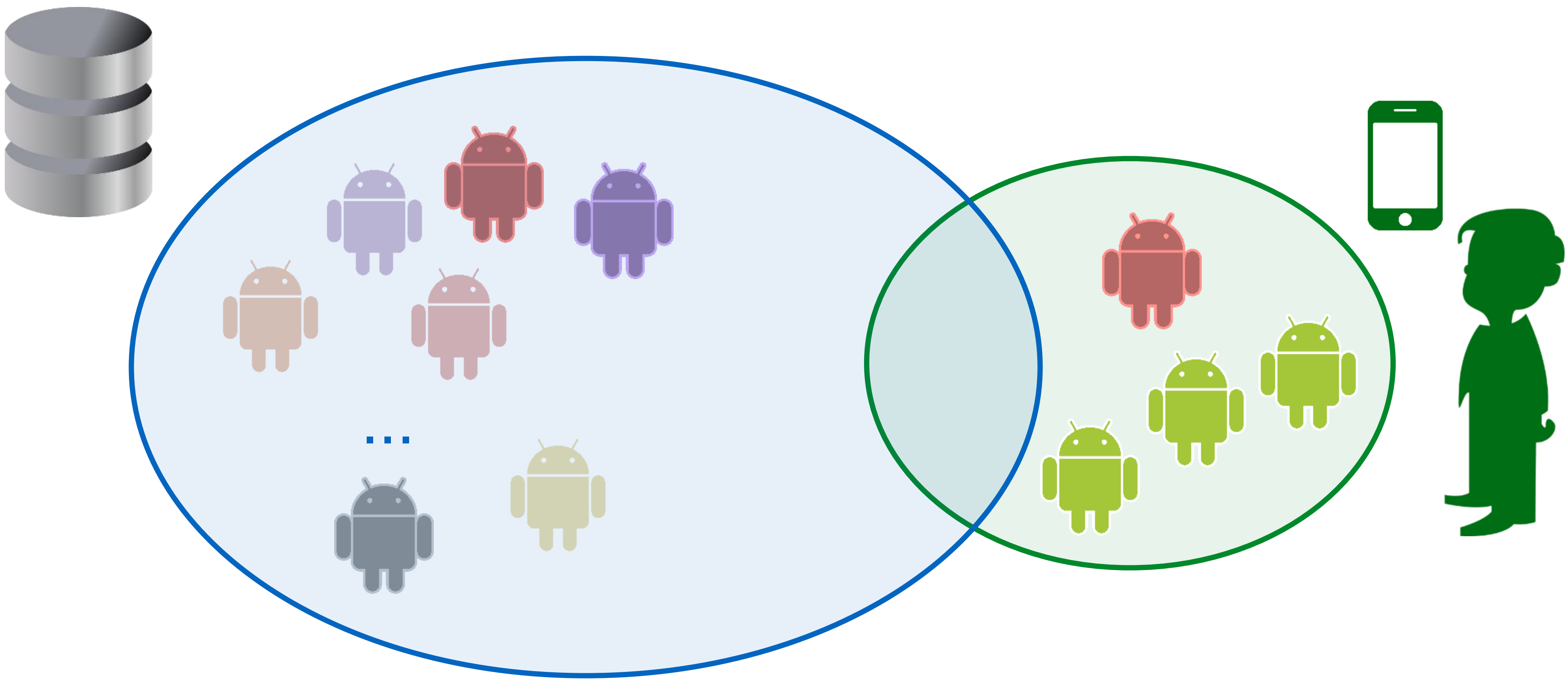
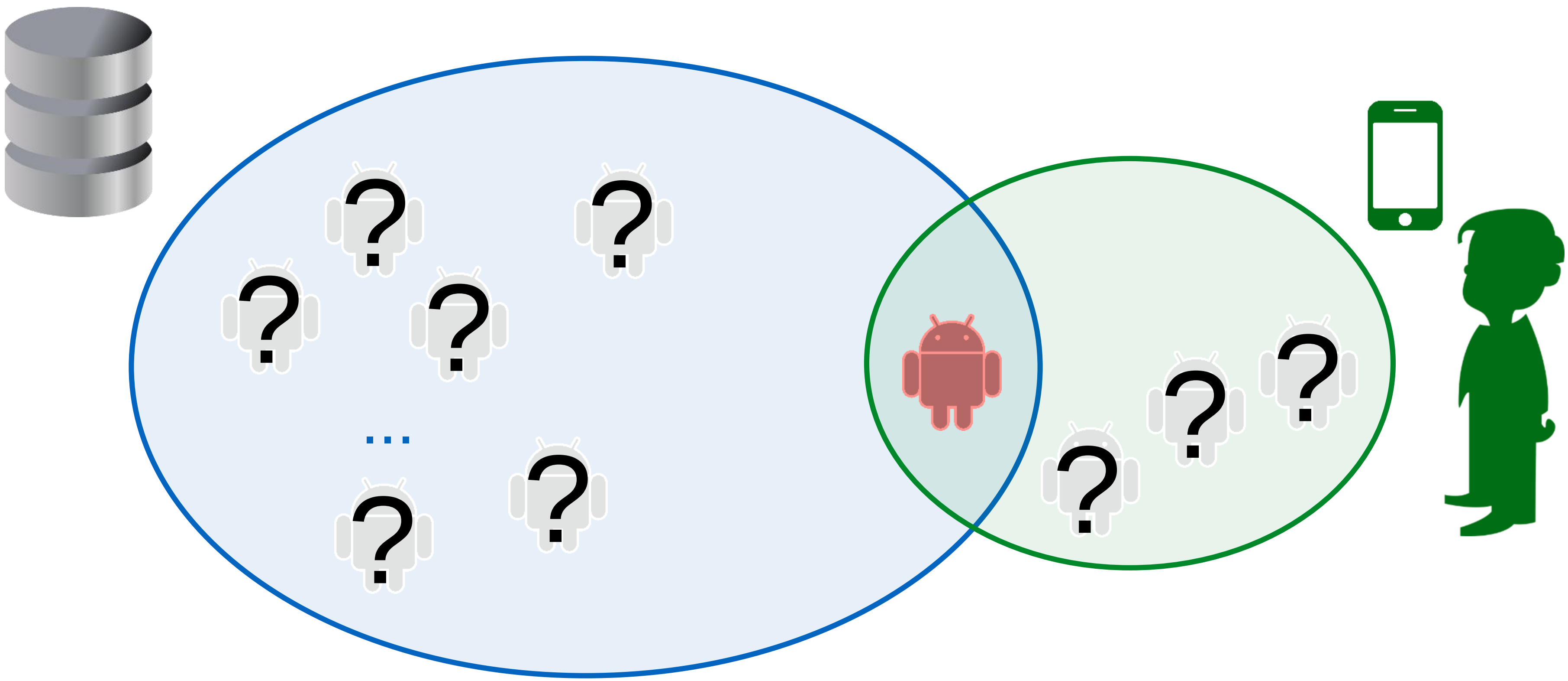
PSI with Unequal Set Sizes – Malware Detection Service



KASPERSKY N_A $\gg$ N_B

3 Mio 95 [TLP+17]

PSI with Unequal Set Sizes – Malware Detection Service



KASPERSKY

$N_A \gg N_B$

3 Mio | 95

[TLP+17]

What do we have?

- **OT-based protocols efficient for $N_A \approx N_B$**
  - Garbled BF based protocols [DCW13,RR17]
  - Hashing-based protocols [PSZ14,PSSZ15,KKRT16]

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  - Based on public-key crypto: OPE [FNP04], DH [HFH99]
  - Based on Oblivious PRF evaluation: NR [FIPR05,HL08], AES [PSSW09], RSA [CT10]

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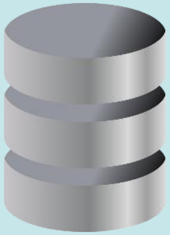
Our Contributions

Improve existing linear complexity protocols for unequal set sizes

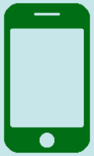
Prototype implementation of improved protocols

Further extensions for real-world applications

Precomputed PSI – Three Phases



$|N_A| \gg |N_B|$



Base Phase

Data-independent, depends on $N_B^{\max}$ maximum number of client inputs

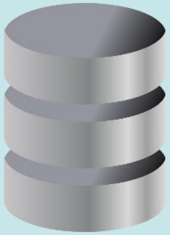
Setup Phase

Depends on the N_A elements in the database

Online Phase

Depends on the N_B elements in the client set

Precomputed PSI – Three Phases



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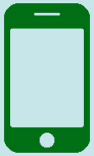

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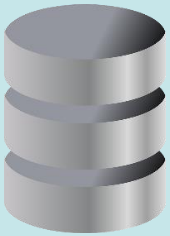

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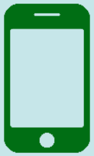

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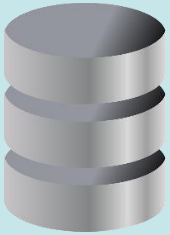

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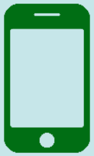

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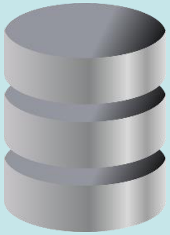

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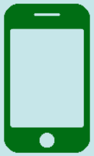

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Same for all clients?

Online Phase

Depends on the N_B elements in the client set

Computation on the client's few elements is fast

Bloom filter

H_1 H_2 ... H_k

1	2	...	*i*		...			*j*			...			*n*
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bloom filter

e: 004912345678910

H_1 H_2 ... H_k

1	2	...	i		...			j			...			n
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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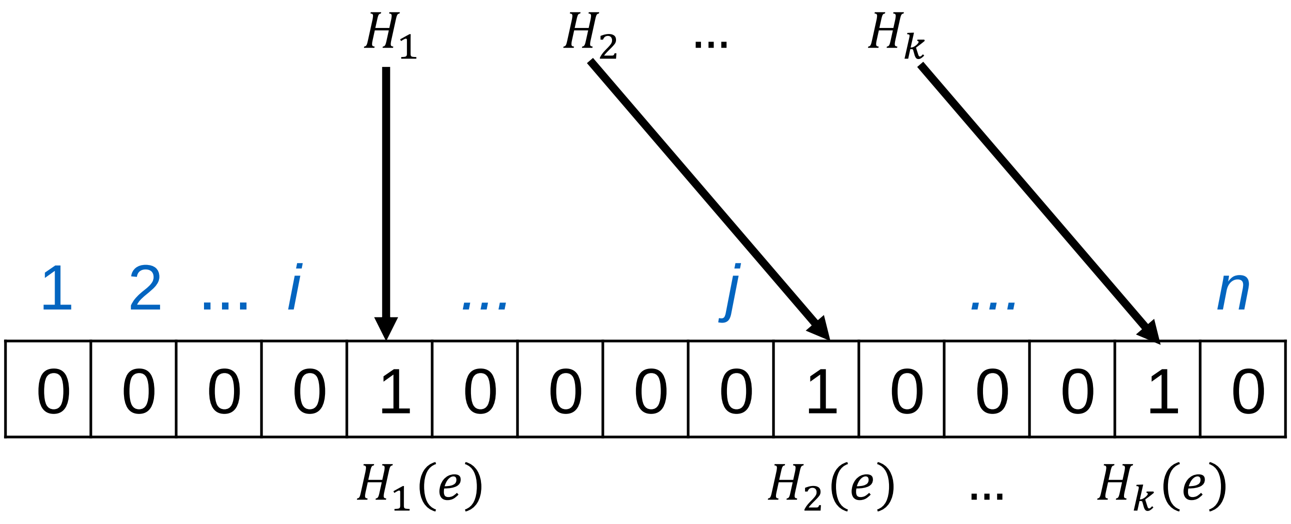

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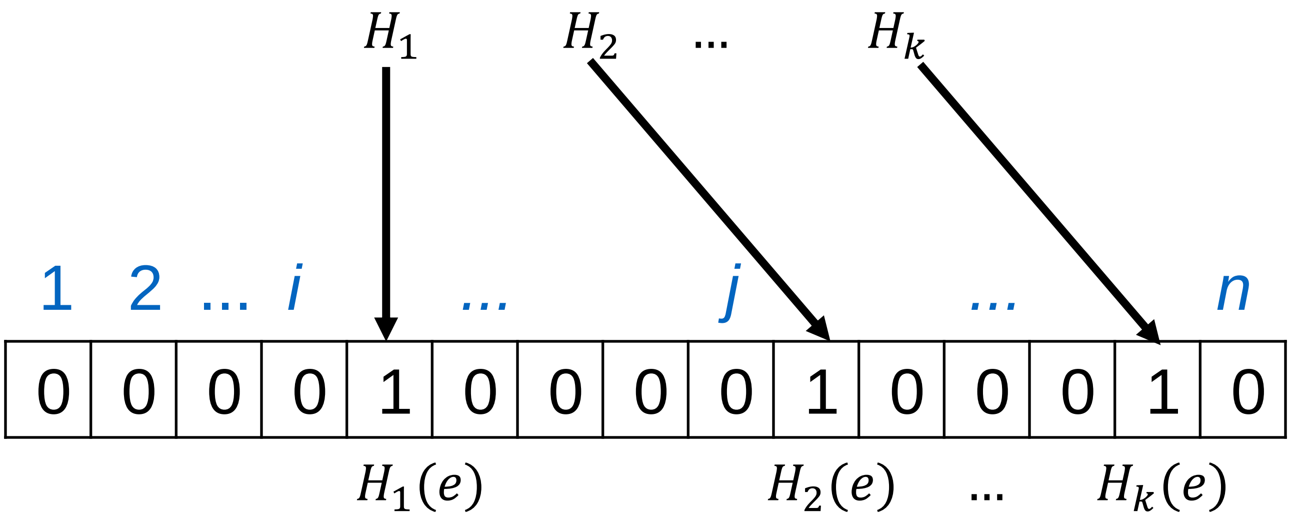
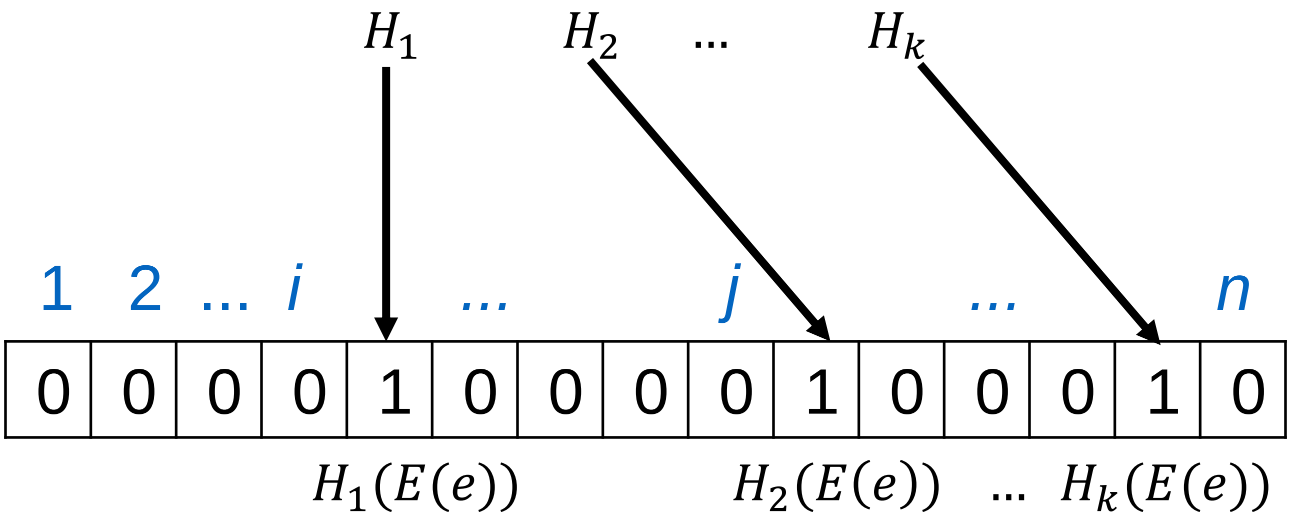


Bloom filter

$E(e)$: fti45jxcfuu984fghdr56fguew91jm



Efficient and Secure Updates

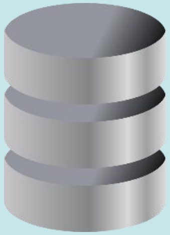
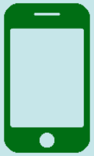
Insertion in Bloom filter

$E(e)$: fti45jxcfuu984fghdr56fguew91jm

$$H_1(E(e)), H_2(E(e)), \dots, H_k(E(e))$$

Deletion: Counting Bloom filter

Precomputed PSI – PSI with PRF: RSA-PSI, NR-PSI, GC-PSI

 $\lvert N_A \rvert$	$\gg$	$\lvert N_B \rvert$ 
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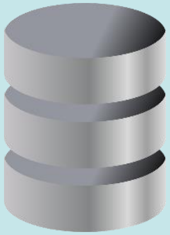
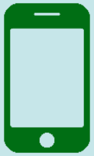
 $\lvert N_A \rvert$	$\gg$	$\lvert N_B \rvert$ 
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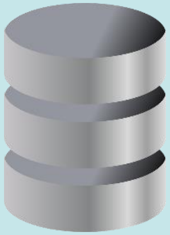
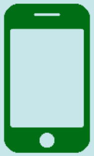
 $\lvert N_A \rvert$	$\gg$	$\lvert N_B \rvert$ 
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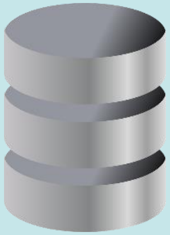
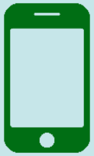
Precomputed PSI – PSI with Diffie-Hellman – DH-PSI

 $\lvert N_A \rvert$	$\gg$	$\lvert N_B \rvert$ 
Key generation α	**Base Phase**	Key generation β
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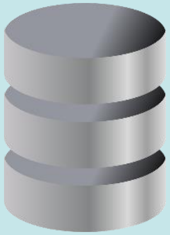
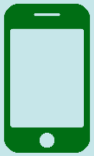
 $\lvert N_A \rvert$	$\gg$	$\lvert N_B \rvert$ 
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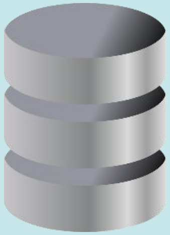
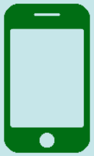
 $\lvert N_A \rvert$	$\gg$	$\lvert N_B \rvert$ 
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Our Contributions

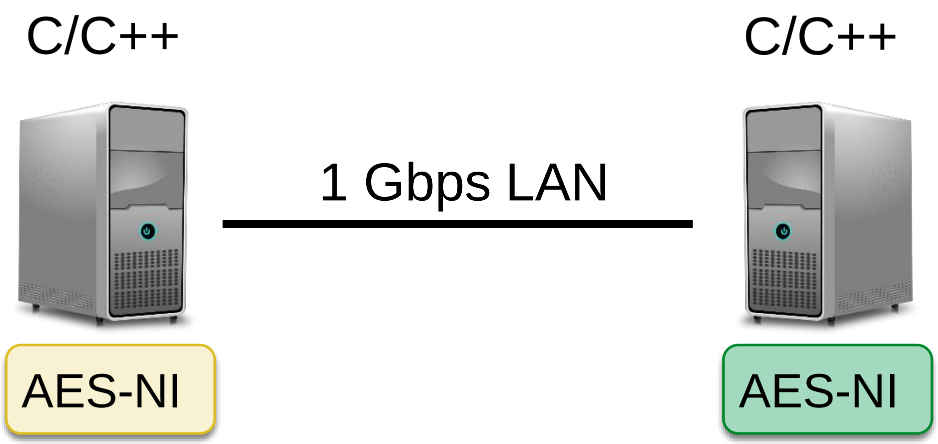
Improve existing linear complexity protocols for unequal set sizes

Prototype implementation of improved protocols

Further extensions for real-world applications

Computation and Communication – PC Malware Detection

$$\mathrm{FPR} = 10^{-3}$$
$$N_A = 2^{20}$$
$$N_B = 128$$
$$N_B^{\max} = 256$$



Protocol\Phase	Base phase		Setup phase		Online phase	
RSA-PSI	14 ms	0 MB	57.4 min	1.8 MB	0.9 sec	0.1 MB
ECC-DH-PSI	1 ms	0 MB	22.1 min	35.5 MB	0.4 sec	0.1 MB
NR-PSI	0.1 sec	2.2 MB	12.6 min	1.8 MB	1.4 sec	0.5 MB
AES-NI GC-PSI	1.3 sec	44.5 MB	0.3 sec	1.8 MB	0.3 sec	0.5 MB

Computation and Communication – Mobile Malware Detectio

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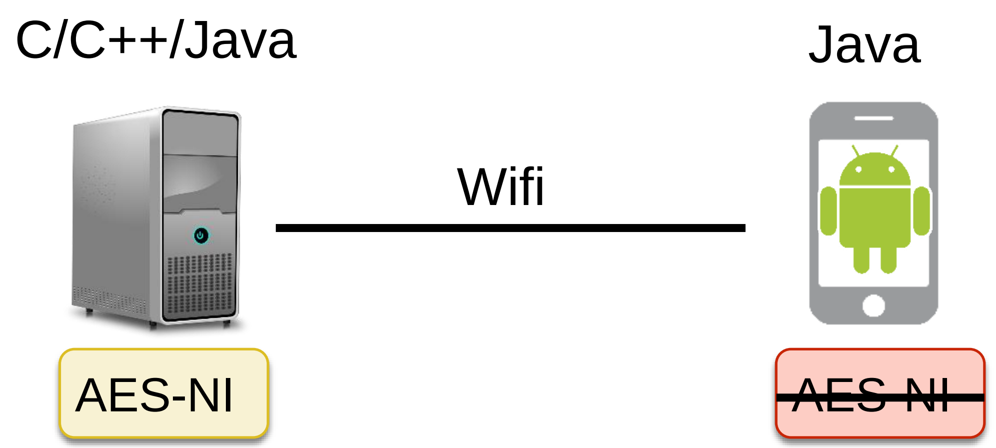

	Protocol\Phase	Base phase		Setup phase		Online phase	
	RSA-PSI	1.4 sec	0 MB	57.4 min	1.8 MB	7.7 sec	0.1 MB
~~ECC~~	DH-PSI	1 ms	0 MB	8.6 min	35.5 MB	2.9 sec	0.1 MB
	NR-PSI	0.7 min	2.2 MB	12.7 min	1.8 MB	31.6 sec	0.5 MB
~~AES-NI~~	GC-PSI	7.6 min	44.5 MB	1.7 sec	1.8 MB	18.1 min	0.5 MB

Computation and Communication– Mobile Messaging

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$N_A = 2^{30}$ (1 billion users)

$N_B = 256$

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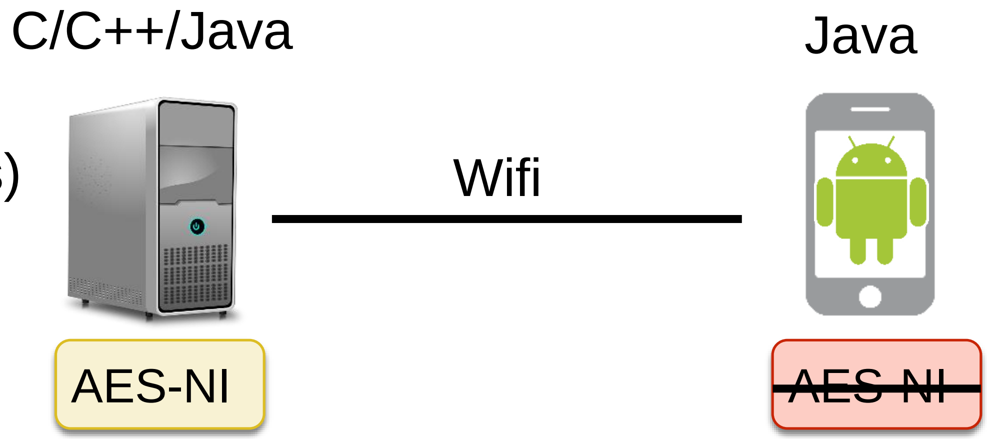

Protocol\Phase	Base phase		Setup phase		Online phase	
RSA-PSI	2.7 sec	0 MB	40.8 days	5.4 GB	15.4 sec	0.2 MB
~~ECC~~ DH-PSI	1 ms	0 MB	6.1 days	256 GB	5.9 sec	0.2 MB
NR-PSI	0.7 min	4.2 MB	9.0 days	5.4 GB	1.1 min	1.0 MB
~~AES-NI~~ GC-PSI	7.6 min	89.0 MB	0.5 hour	5.4 GB	0.6 hour	1.0 MB

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C/C++/Java

AES-NI

Wifi

Java

~~AES-NI~~

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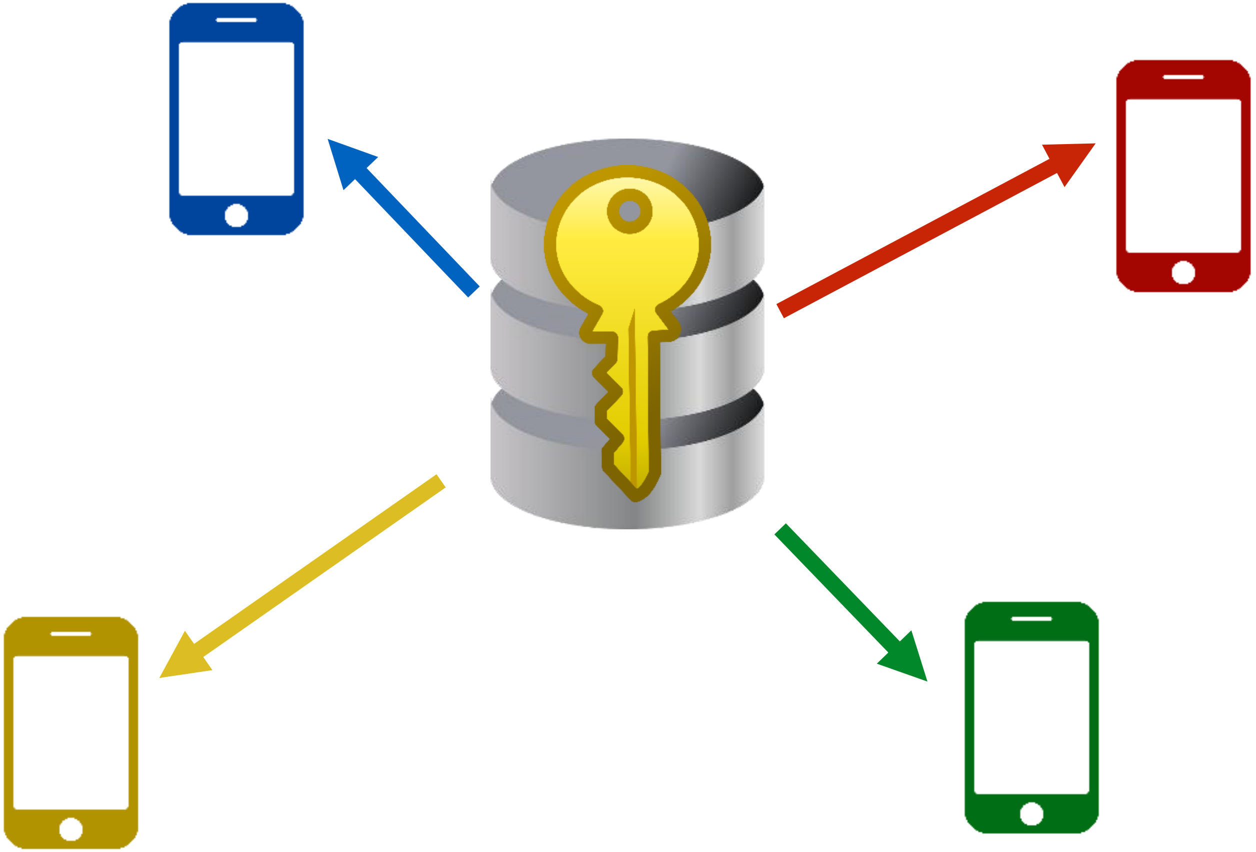
Same Encrypted Database for Multiple Clients

Same Encrypted Database for Multiple Clients

Content delivery network (CDN)



Effect on Performance – Mobile Messaging

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Cuckoo filter in follow up work [RA17] → 4 GB

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~~DH-PSI~~	~~1 ms~~	~~0 MB~~	~~6.1 days~~	~~256 GB~~	~~11.8 sec~~	~~0.3 MB~~
NR-PSI	0.7 min	4.2 MB	~~9.0 days~~	5.4 GB	2.1 min	2.0 MB
GC-PSI	7.6 min	89.0 MB	~~0.5 hours~~	5.4 GB	1.2 hours	2.0 MB

Summary

Improve existing linear complexity protocols for unequal set sizes

Prototype implementation of improved protocols

Further extensions for real-world applications

Thank you for your attention!

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