Faster Private Set Intersection based on OT Extension

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Private Set Intersection (PSI)

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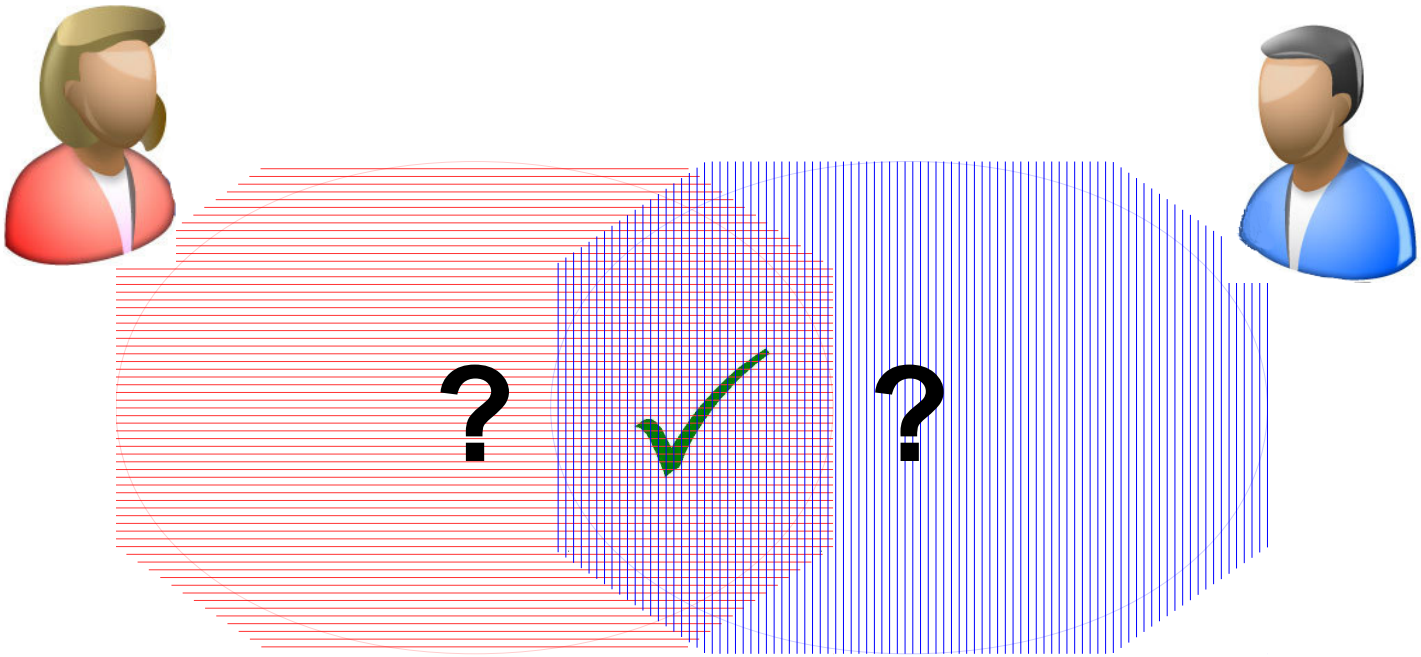

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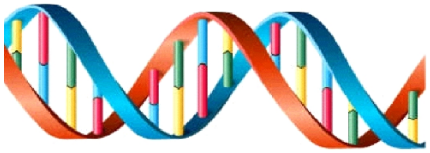
Applications

Secure database join

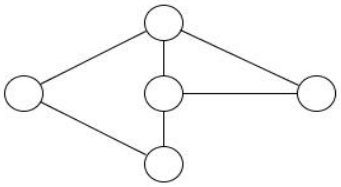
Common contacts

Botnet detection

Cheater detection in online games



Testing human genomes



Relationship path discovery

A naïve PSI protocol

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Input: $x_1, \ldots, x_n$

Input: $y_1, \ldots, y_n$

$H(x_1), \ldots, H(x_n)$

$H(y_1), \ldots, H(y_n)$ ◄

$H(y_1), \ldots, H(y_n)$

$H(x_i) \stackrel{?}{=} H(y_j)$, for $0 < i, j < n$

- Pro: fast, little communication

- Con: can leak privacy of Bob's inputs

Our Contributions

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- Survey major results on semi-honest PSI

- Optimize existing PSI protocols

- Present a new PSI scheme

- Compare performance of all schemes

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Existing PSI Protocols

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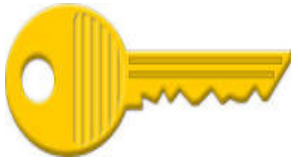
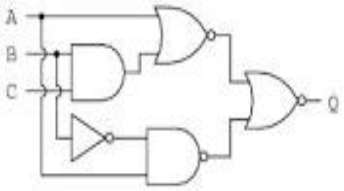
- Public-key Cryptography
  - DH-based Protocol [M86], O(n) pk-crypto
  - Blind RSA Protocol [CT10], O(n) pk-crypto



- Generic Secure Computation
  - Based on Yao's garbled circuits, GMW
  - Circuit in [HEK12], O($n \log n$) sym-crypto



- Oblivious Transfer
  - Only sym-crypto via OT extension [IKNP03]
  - Bloom-filter [DCW13], O(n) sym-crypto

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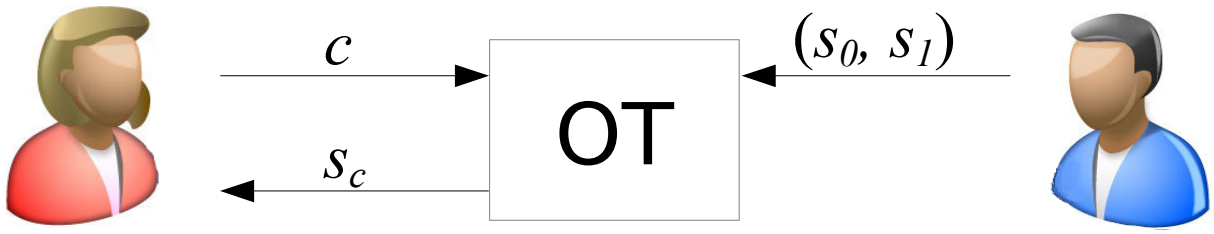
Oblivious Transfer (OT)



- **Input**: Bob holds two strings (s_0, s_1), Alice holds a choice bit c

- **Output**: Alice receives s_c but learns nothing about s_{1-c},
  Bob learns nothing about c

Optimizing Existing Protocols

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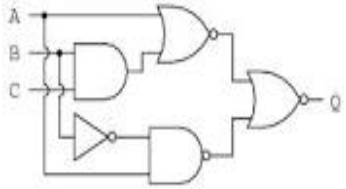
- Improve circuit-based PSI of [HEK12] using GMW
  - Multiplexer complexity independent of bit-length
  - Reduce computation / communication by factor 2
  - Also applicable to other functionalities



- Randomize Garbled Bloom filter of [DCW13]
  - Reduce computation by factor 3
  - Reduce communication by factor 4
  - Whole protocol can be parallelized

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PSI based on OT

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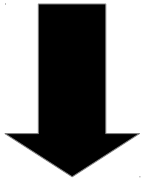
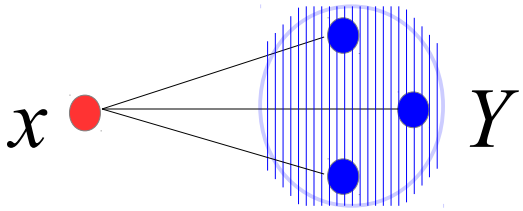
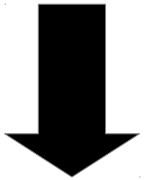
Private Equality Test:

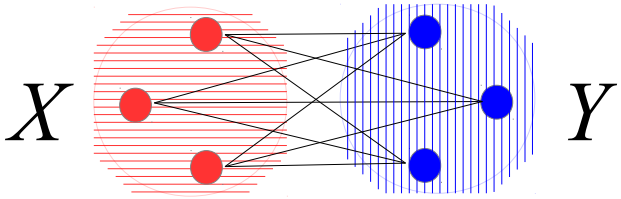


Private Set Inclusion:





Private Set Intersection:



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PSI based on OT (Equality Test)

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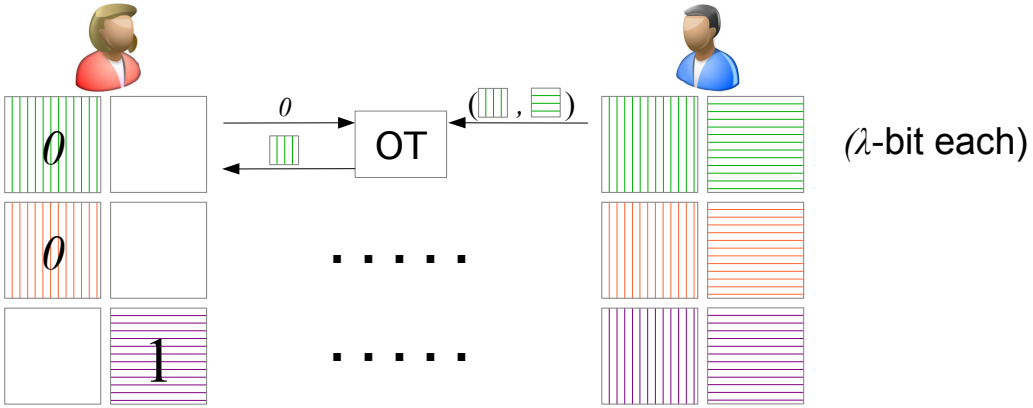
- **Input:** Alice has x, Bob has y. **Output:** $x \stackrel{?}{=} y$

- **Example:** $x = 001, y = 011$



- Bob sends λ-bit mask $0 \oplus 1 \oplus 1$ to Alice

- Alice computes $0 \oplus 0 \oplus 1$ and compares

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PSI based on OT (Set Inclusion)

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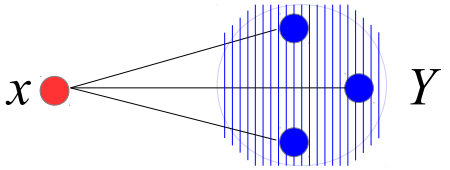
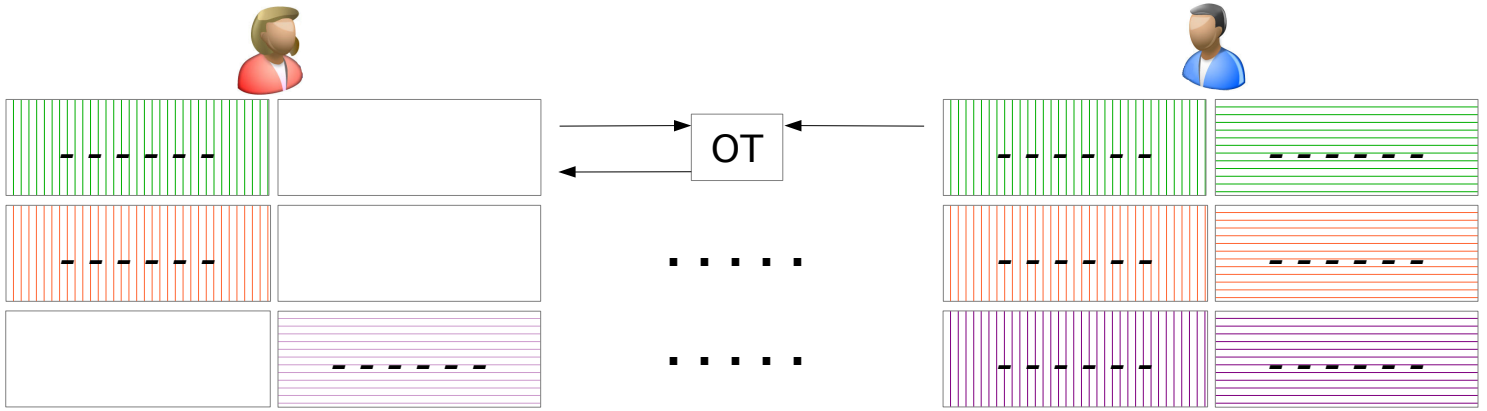
- **Input:** Alice has x, Bob has $Y = \{y_1, \ldots, y_n\}$. **Output:** $x \overset{?}{\in} Y$



- Run n Private Equality Tests in parallel
  - Alice's OT choices for all $y_1, \ldots, y_n$ are the same
  - Send $n\lambda$ bits from Bob to Alice



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PSI based on OT (Set Intersection)

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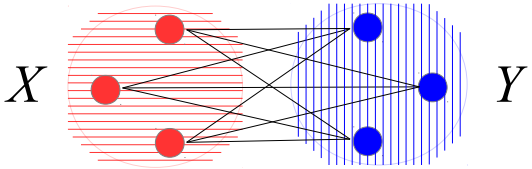
- **Input:** Alice has $X = \{x_1, \ldots, x_n\}$, Bob has $Y = \{y_1, \ldots, y_n\}$.

Output: $X \cap Y$.



- Run n Private Set Inclusions in parallel
  - Requires n^2 comparisons, hence not an option

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Hashing

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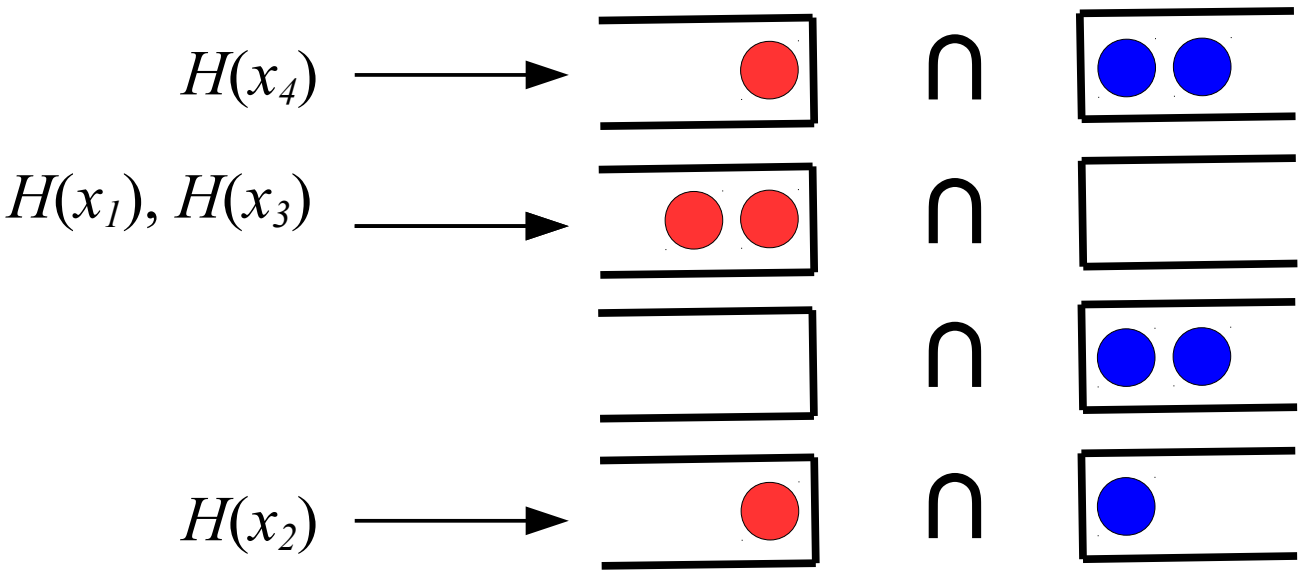
- Hash elements to bins to reduce comparisons

- **Example:** Alice holds $X=\{x_1, \ldots, x_4\}$, Bob holds $Y=\{y_1, \ldots, y_4\}$



- Reduces comparisons from n^2 to $O(n \log n)$

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Comparison Results

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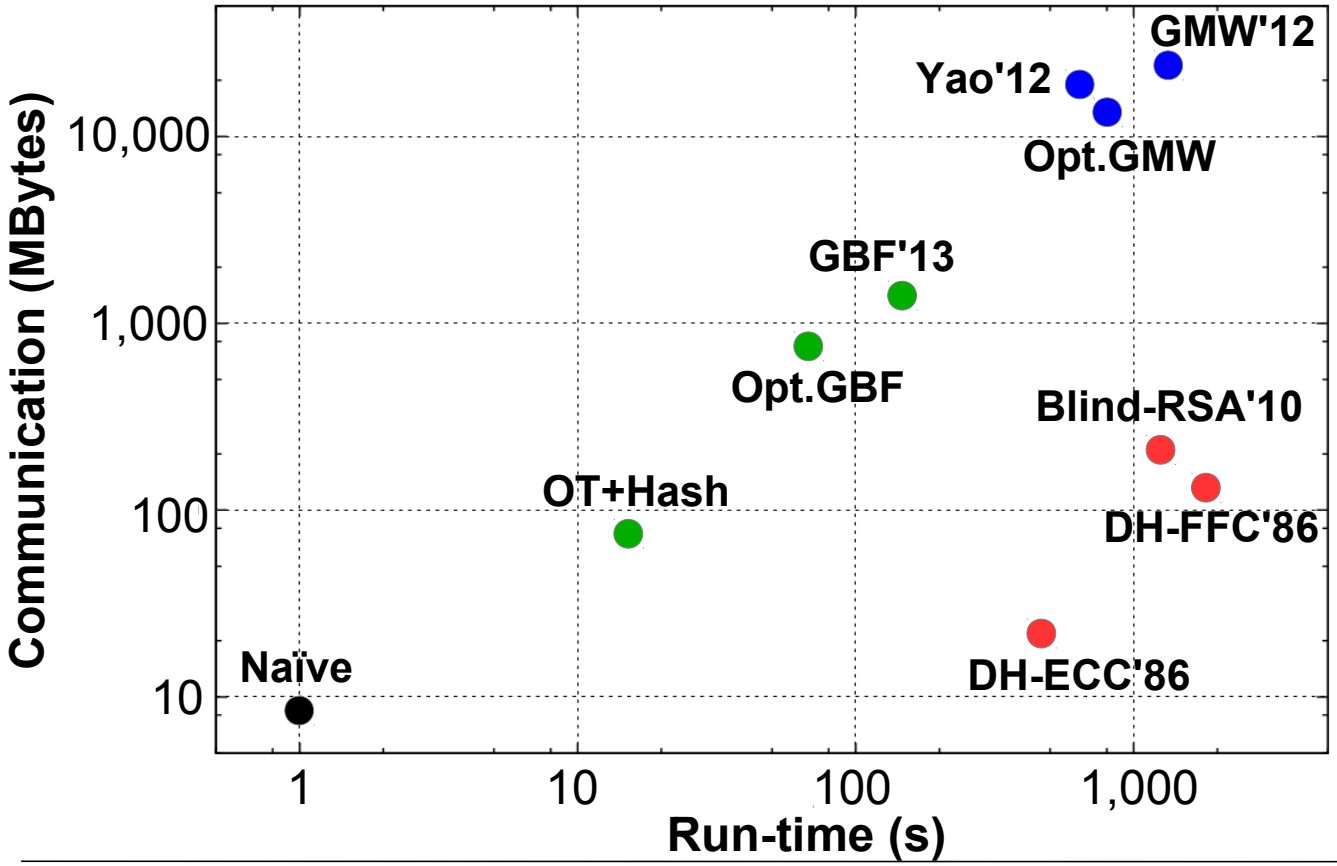
- PSI on $n = 2^{18}$ elements of 32-bit length for 128-bit security on Gbit LAN



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Comparison Results

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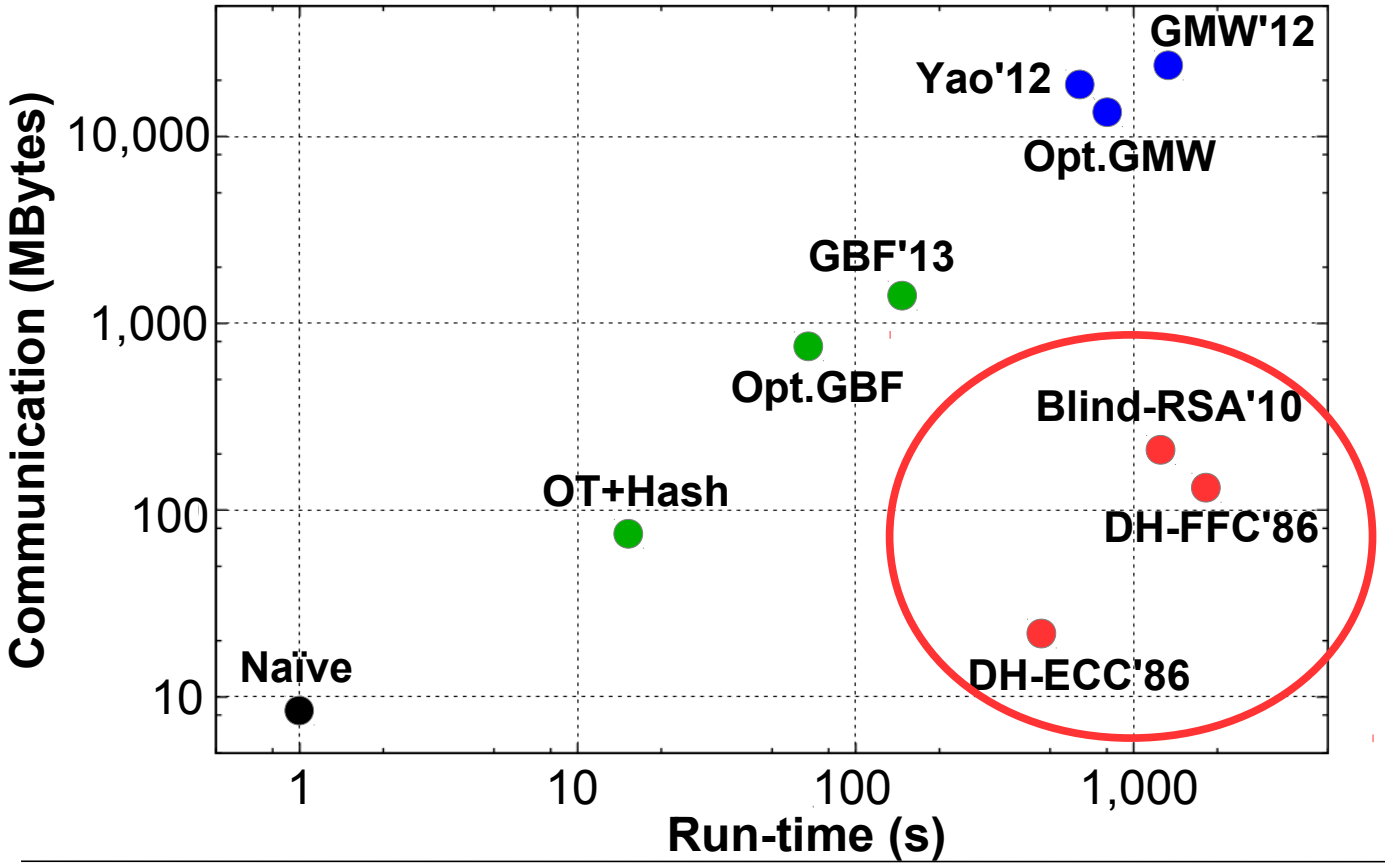

PK-Based:

- high run-time for large security parameters
+ best communication

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Comparison Results

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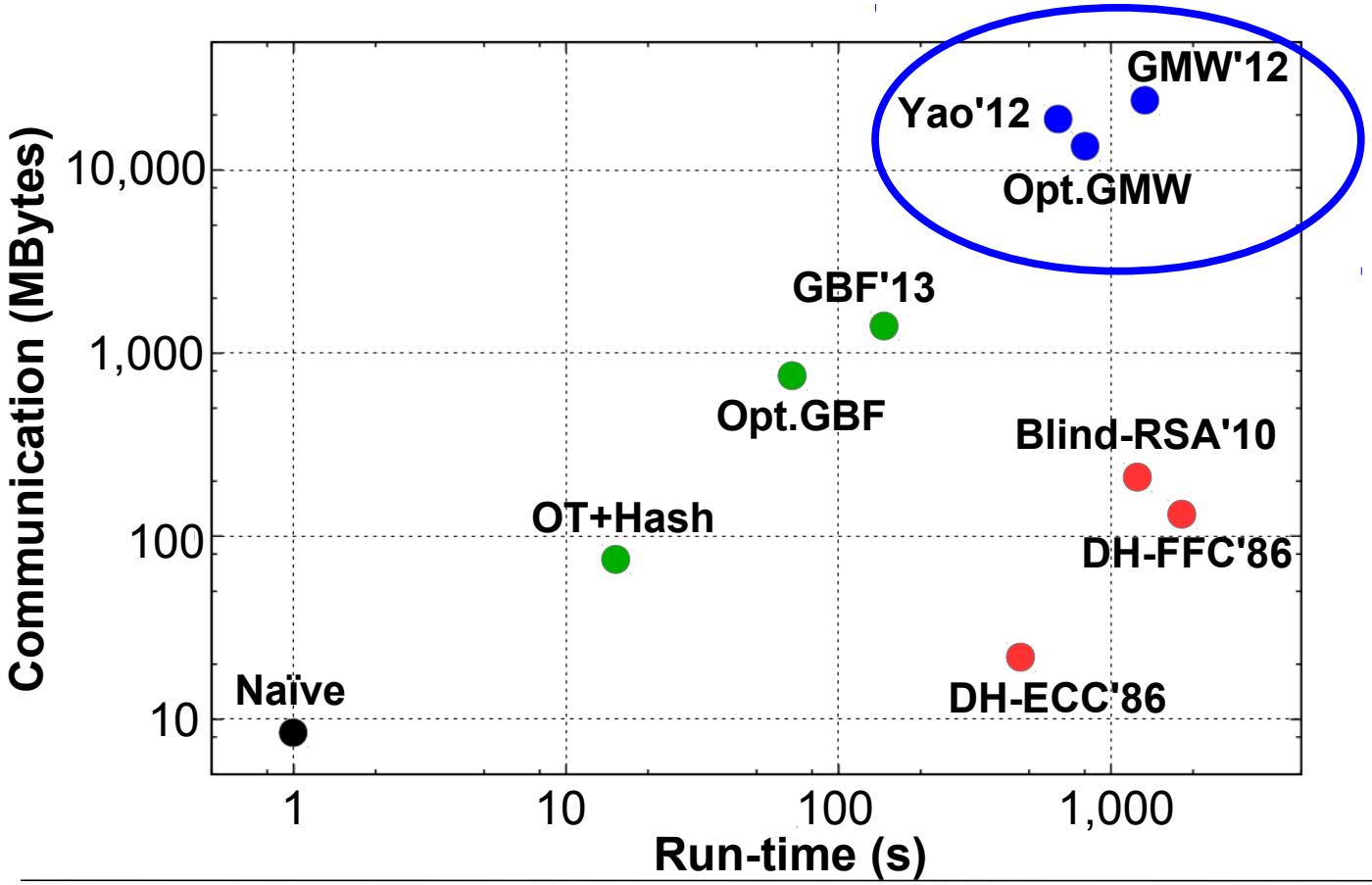

Circuit-Based:
- high run-time & communication
+ easily extensible to arbitrary functions

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Comparison Results

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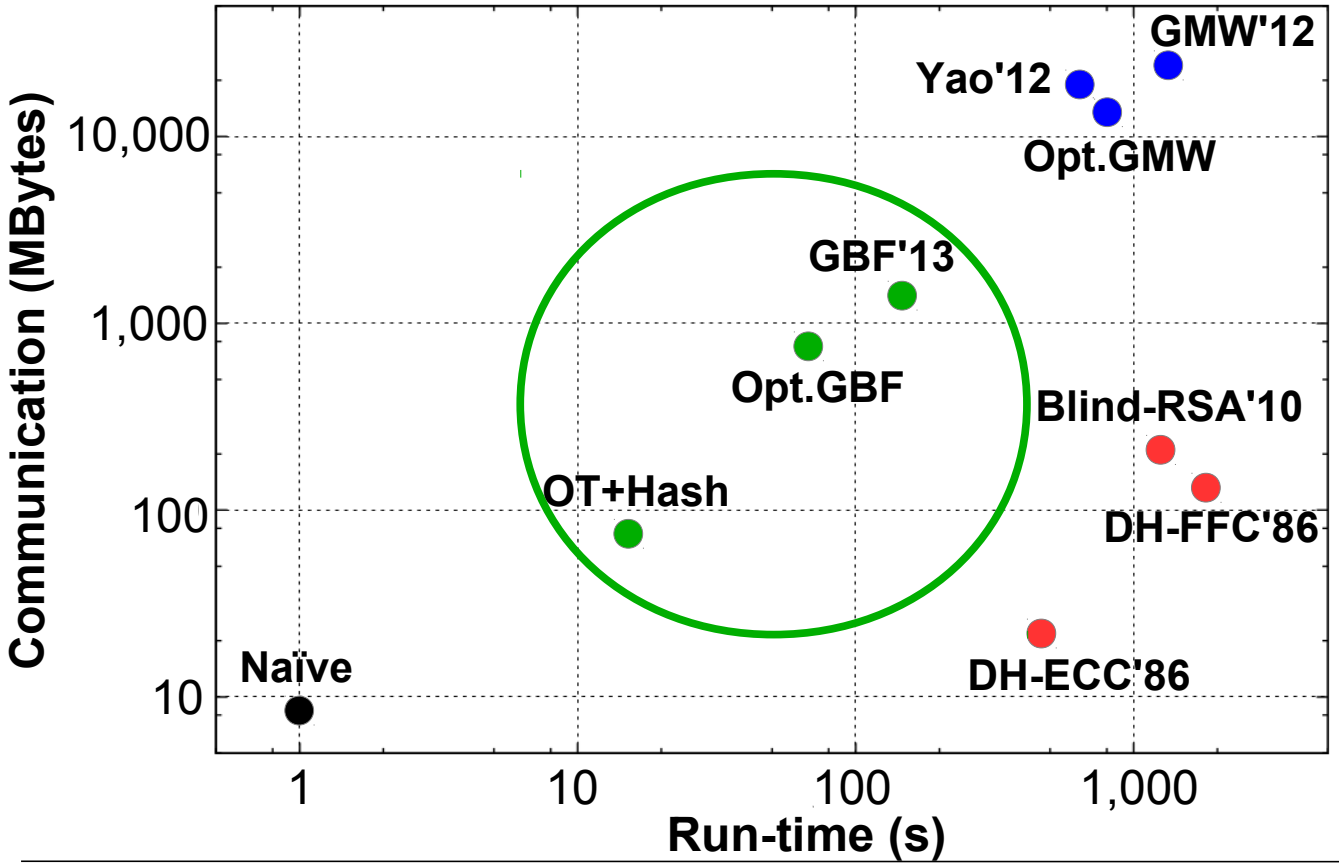

OT-Based:
+ good communication and run-time

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Conclusion

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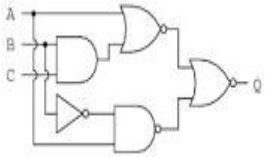
Rule of Thumb:

- OT-based protocols in general case

- DH-based ECC if communication is bottleneck

- Circuit-based protocols for easy extension



Goal: PSI on million element sets in less than 1 second

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Thank you for your attention

References

- [M86] C. Meadows: A more efficient cryptographic matchmaking protocol for use in the absence of a continuously available third party. In IEEE S&P 86.

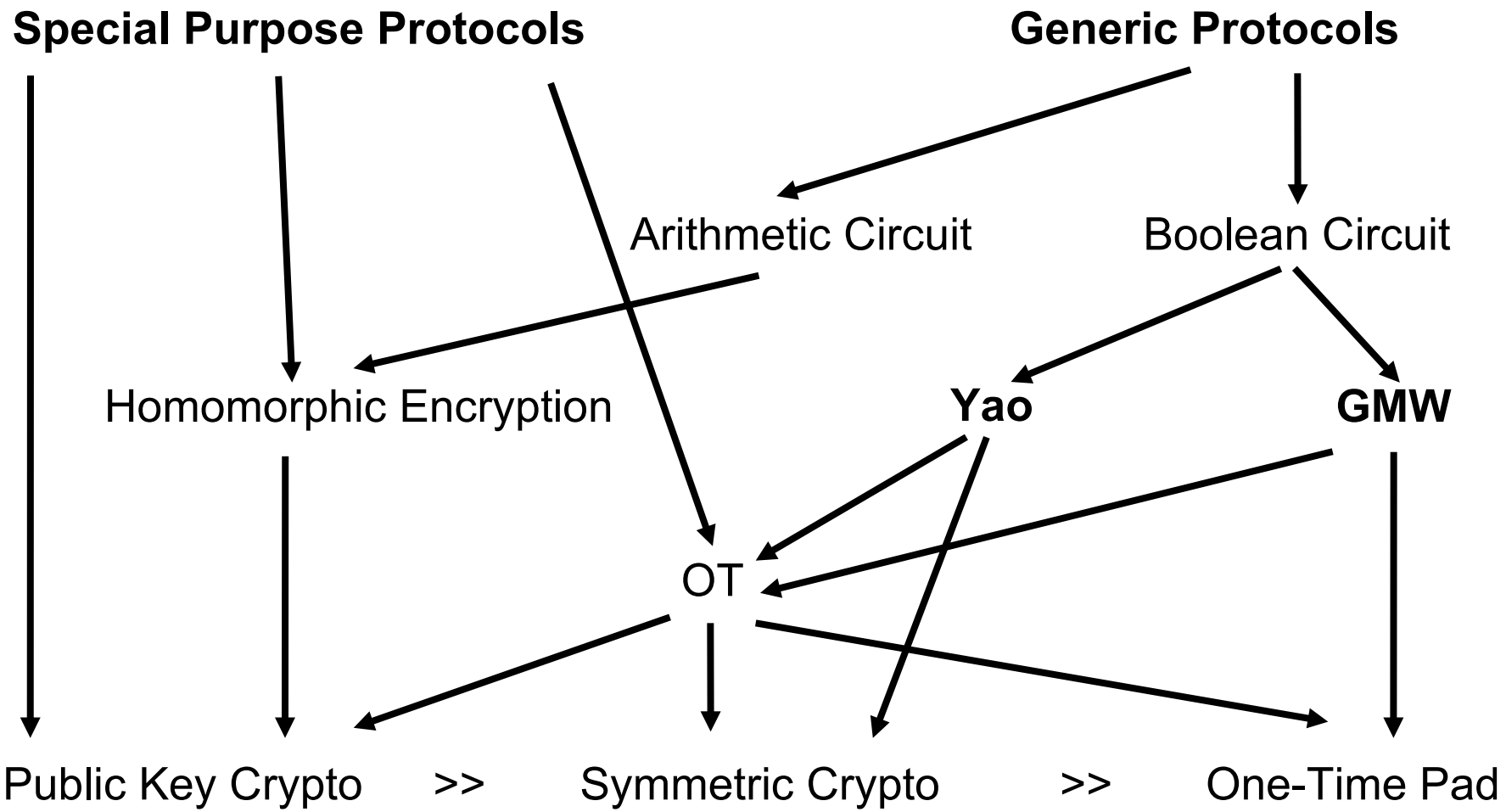
- [CT10] E. De Cristofaro and G. Tsudik: Practical private set intersection protocols with linear complexity. In FC'10.

- [HEK12] Y. Huang, D. Evans, and J. Katz: Private set-intersection: Are garbled circuits better than custom protocols? In NDSS'12.

- [DCW13] C. Dong, L. Chen, and Z. Wen: When private set intersection meets big data: An efficient and scalable protocol. In ACM CCS'13.

- [IKNP03] Y. Ishai, J. Kilian, K. Nissim, E. Petrank: Extending Oblivious Transfers Efficiently. In CRYPTO'03.

Protocol Overview



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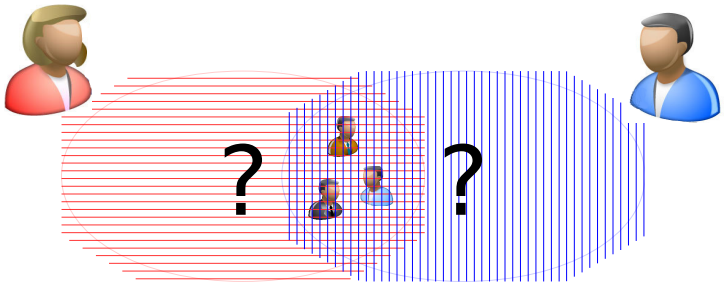
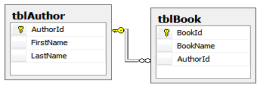
Private Set Intersection



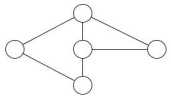
Applications

- Secure Database Join



- Common Contacts

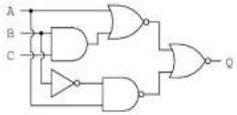
- Relationship Path Discovery



Techniques

- Public-key Cryptography

- Generic Secure Computation



- Oblivious Transfer

Summary

- Optimize & Implement

- New Protocol

- Comparison

1 Mio. elements in 20 seconds on PCs

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Results

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Protocol	Communication	Computation
Naive Hashing	8	1
DH FFC	192	1224
DH ECC	26	416
Blind RSA	132	1982
Circuit + GMW	23400	1304
Circuit + Opt GMW	14040	762
Yao	20736	609
Garbled Bloom	1393	154
Opt. GBF	740	68
OT + hashing	78	14