Thresholding Symmetric-Key Primitives Based on General-Purpose Actively Secure MPC

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## Our Goal

<table>
<thead>
<tr>
<th>Subcategory: Type</th>
<th>(Sub)subcategory #</th>
<th>Family of primitives</th>
<th>Some [Primitives] and/or {Threshold Modes}</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1.4: Symmetric</td>
<td>C1.4.1: AES</td>
<td>(en/de)cipher</td>
<td>[encipher, decipher]</td>
</tr>
<tr>
<td></td>
<td>C1.4.2: KDM/KC</td>
<td>(for 2KE)</td>
<td>[Hash, CMAC, HMAC, KMAC]</td>
</tr>
</tbody>
</table>

- With support of all I/O interfaces
  - {NSS, SSI, SSO, SSIO}
  -  
- With support of all primitives
  - AES, SHA[23], [CHK]MAC, etc
- With possibility to support C2.4
  - C2.4, for symmetric-key primitives (e.g., TF enciphering/deciphering), and hashing-related primitives for key derivation and key confirmation;
Our Solution

Based on generic multi-party computation protocols for Boolean circuits!

Pros:

- Only need to handle one protocol and one implementation
- Usable in other applications

Cons: May not be as efficient as customized protocols

- But the gap is small: most symmetric-key primitives have little structure for improvement
Our Philosophy

As fast as possible with high security confidence.

High security confidence:

- Active security in the universal composability model
- Tolerate a static corruption of \( n-1 \) parties out of \( n \) parties.
- Concrete security
- Conservative assumptions

Two solutions

- A solution using only NIST-standardized primitives
  - E.g, AES as ideal cipher, SHA3 as random oracle, and NIST-approved curves.
- A (more efficient) solution using primitives close to what NIST already standardized
Learning Parity w/ Noise

Authenticated Garbling

Authenticated Beaver Triple

Correlated OT

Thresholding:

- SHA3
- GMAC
- GCM
- Random oracle
- DDH-secure curves

Tweakable (circular) correlation-robust hash

Ideal cipher

Base OT
Tweakable (circular) correlation-robust hash

- Use of Fixed-key AES by Bellare et al. [SP:BHKR13], and then by Zahur et al. [EC:ZahRosEva16] for garbling
  - Then, a lot of unprincipled used

- Modular proof by Guo et al. [SP:GKXY20]
  - Still suffer from birthday bound

- Near optimal concrete security by Guo et al. [C:GKWWY20]
Correlated OT

- [C:IKNP03] is the most widely used correlated OT with passive security
  - [C:KelOrsSch15] is the most widely used COT with active security

- Silent OT [C:BCGIKS19, CCS:BCGIKRS19, CCS:SGRR19, CCS:YWLZW20, ...]
  - All based on some variations of Learning Party w/ Noise
  - Very small communication, moderate computation

- SoftSpokenOT [C:Roy22]
  - No LPN assumption, more rigours analysis of consistency check
  - Smaller communication in trade of more AES-like computation
Authenticated Beaver Triples

Pairwise IT-MAC on “normal” Boolean Beaver Triples

- [C:NNOB12] – Concept and first construction

- [AC:FKOS15], [JC:BLNNOOSS21] – Improved efficiency, two layers of bucketing

- [CCS:WanRanKat17], [CCS:YanWanZha20] — Improved efficiency, one layers of bucketing, w/ a row of GC-like table
Authenticated Garbling

  - Concurrent to the multi-party extension of WRK: [AC: HazSchSor17]

- [C: KRRW, CCS: YanWanZha20] — Improved online and offline
  - Online can be as small as a half-gate + O(1)
  - Offline works with “leaky” COTs

- [C: DLIO22, EC: CWYY23]
  - Rely on single-sided secure authenticated triples and cheap COT/VOLEs
  - Nearly optimal in communication in trade of high computation
Learning Parity w/ Noise
Authenticated Beaver Triple
Authenticated Garbling
Authenticated GMW
Tweakable (circular) correlation-robust hash
Ideal cipher
Correlated OT
Base OT
Random oracle
DDH-secure curves

Thresholding:
SHA3
GMAC
GCM
...
Planned Submission

Protocols

- Authenticated garbling
- Authenticated GMW “TinyOT”

Gadgets:

- Tweakable robust hash
- Correlated OT
- Garbling scheme
- Authenticated triples