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BETTER.

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Downgradable Identity-based Encryption and Applications

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#RSAC

- Context
- Model
- Generic Transformations
- Construction

General Context

Identity-Based Encryption

Alice

$\xrightarrow{\mathsf{C} = \mathsf{Encrypt}(\text{'Bob'}, M)}$

Bob

M

$M = \mathsf{Decrypt}(\mathsf{usk}_{\mathsf{Bob}}, C)$

History of IBE

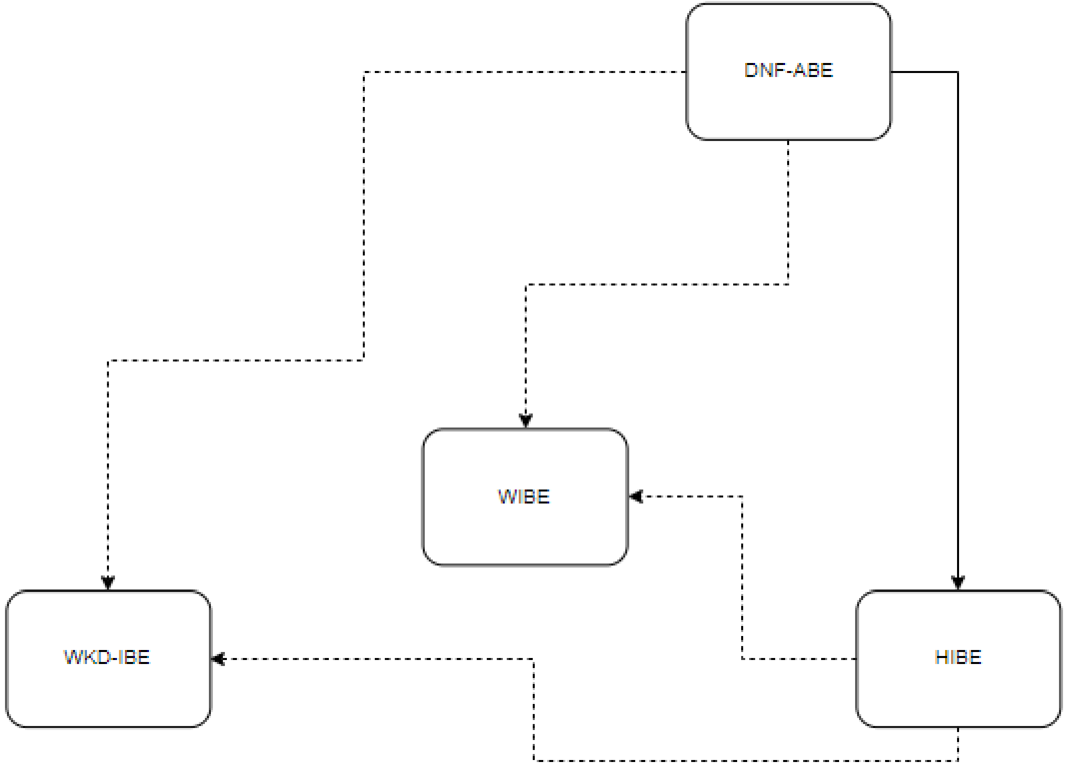
- Shamir ‘84
- Boneh-Franklin, Cocks ‘01
- Boneh-Boyen, Waters ’05
- Waters ’09,
- Chen-Wee, Blazy –Kiltz-Pan

- Context
- Model
- Generic Framework
- Construction
- Applications

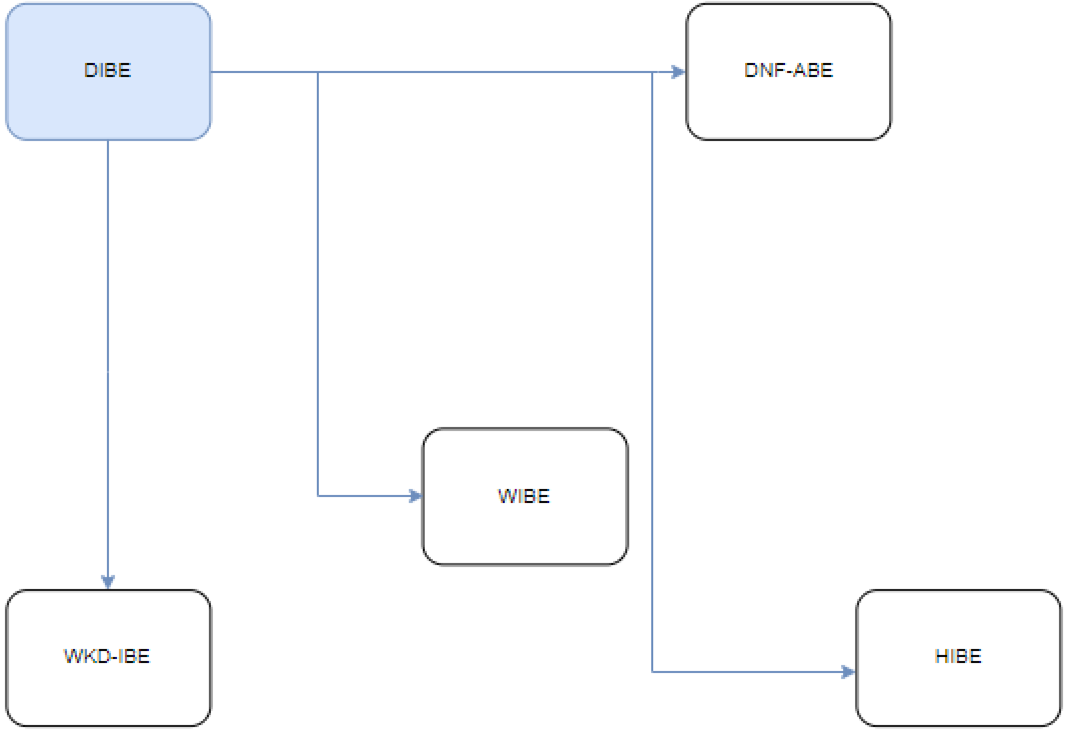
So Many Variants

- Hierarchical IBE
- Wildcarded IBE
- Wicked IBE
- …

Relations ?



Relations ?



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Model

Identity-Based Encryption

- 4 algorithms:
  - Keygen: Generates mpk, msk
  - USKGen(id, msk): Generates usk[id]
  - Enc(mpk,id): Generates a capsule C leading to a key K for id
  - Dec(C,usk[id]): Recovers K' from C

Procedure Initialize:
$(\mathsf{mpk}, \mathsf{msk}) \xleftarrow{\$} \mathsf{Gen}(\mathfrak{K})$
Return mpk

Procedure USKGen(id):
$\mathcal{Q}_{\mathsf{ID}} = \mathcal{Q}_{\mathsf{ID}} \cup \{\mathsf{id}\}$
Return $\mathsf{usk}[\mathsf{id}] \xleftarrow{\$} \mathsf{USKGen}(\mathsf{msk}, \mathsf{id})$

Procedure Enc(id*): //one query
$(\mathsf{sk}^*, \mathsf{C}^*) \xleftarrow{\$} \mathsf{Enc}(\mathsf{mpk}, \mathsf{id}^*)$
$\boxed{\mathsf{sk}^* \xleftarrow{\$} \mathcal{K}; \mathsf{C}^* \xleftarrow{\$} \mathsf{CS}}$
Return $(\mathsf{sk}^*, \mathsf{C}^*)$

Procedure Finalize(β):
Return $(\mathsf{id}^* \notin \mathcal{Q}_{\mathsf{ID}}) \wedge \beta$

Downgradable Identity-Based Encryption

- *5* algorithms:
  - Keygen: Generates mpk, msk
  - USKGen(id, msk): Generates usk[id]
  - Enc(mpk,id): Generates a capsule C leading to a key K for id
  - Dec(C,usk[id]): Recovers K' from C
  - USKDown(usk[id],id'): Return usk[id'] if id' << id

  - Given a key for an id, one can deduce a key for id' if id' can be obtained by replacing some 1 in id by 0. (101 << 111)

Downgradable Identity-Based Encryption

Procedure Initialize:

$(\mathsf{mpk}, \mathsf{msk}) \xleftarrow{\$} \mathsf{Gen}(\mathfrak{K})$

Return mpk

Procedure USKGen(id):

$\mathcal{Q}_{\mathsf{ID}} = \mathcal{Q}_{\mathsf{ID}} \cup \{\mathsf{id}\}$

Return $\mathsf{usk}[\mathsf{id}] \xleftarrow{\$} \mathsf{USKGen}(\mathsf{msk}, \mathsf{id})$

Procedure Enc(id*): //one query

$(\mathsf{sk}^*, \mathsf{C}^*) \xleftarrow{\$} \mathsf{Enc}(\mathsf{mpk}, \mathsf{id}^*)$

$\boxed{\mathsf{sk}^* \xleftarrow{\$} \mathcal{K}; \mathsf{C}^* \xleftarrow{\$} \mathsf{CS}}$

Return $(\mathsf{sk}^*, \mathsf{C}^*)$

Procedure Finalize(β):

Return $(\neg(\mathsf{id}^* \preceq \mathcal{Q}_{\mathsf{ID}})) \wedge \beta$

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Transformations

Wildcard Identity-Based Encryption

- Allows * in targeted identities

$$\mathsf{id}[2i, 2i+1] = \begin{cases} 01 & \text{if } \mathsf{wid}[i] = 0 \\ 10 & \text{if } \mathsf{wid}[i] = 1 \\ 00 & \text{otherwise.} \end{cases}$$

Hierarchical Identity-Based Encryption

- Allows to derive keys for lower level
  - This means* at the end of original identities

$$\mathsf{id}[2i, 2i+1] = \begin{cases} 01 & \text{if } \mathsf{hid}[i] = 0 \\ 10 & \text{if } \mathsf{hid}[i] = 1 \\ 11 & \text{otherwise}(\mathsf{hid}[\mathrm{i}] = \bot). \end{cases}$$

Wicked Identity-Based Encryption

- Allows to derive keys for lower level
  - This means * in the original identities

$$\mathrm{id}[2i, 2i+1] = \begin{cases} 01 & \text{if } \mathsf{wkdid}[i] = 0 \\ 10 & \text{if } \mathsf{wkdid}[i] = 1 \\ 11 & \text{if } \mathsf{wkdid}[i] = * \end{cases}$$

Transformations

- All those transformations are tight
- However they use a space of size 4 for a ternary alphabet.
  - It could be improve, but would not drastically improve the tightness

Attribute-Based Encryption

- User keys have 1 where they have the attribute
- Ciphertext have a 0 where an attribute is not mandatory
- If the policy < attributes, a user can properly downgrade his key

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Construction

Downgradable Identity-Based Encryption

- Can be constructed by adapting BKP'14
  - Can be instantiated under any k-MDDH assumption (SXDH, Dlin,…)
  - Depending on the use case, it is possible to ensure that the downgraded key is indistinguishable from a fresh one.
  - Encapsulation is only k+1 elements (k=1 for SXDH)
  - Same goes for user keys

Wicked / Wildcard Identity-Based Encryption

Name	|pk|	|usk|	|C|	assump.	Sec	Loss
WKD [AKN07]	$n+4$	$n+2$	2	BDDH	Sel. standard	$O(nq_k)$
WKD [AKN07]	$(n+1)n+3$	$n+2$	2	BDDH	Full standard	$O(q_k^n)$
WKD-DIBE	$4n+2$	$3n+5$	5	DLin (any $k-$MDDH)	Full standard	$O(q_k)$
SWIBE [KLLO18]	$n+4$	$2n+3$	4	ROM	Full	$O((n+1)(q_k+1)^n)$
WIBE [BDNS07]	$(n+1)n+3$	$n+1$	$(n+1)n+2$	BDDH	Full standard	$O(n^2q_k^n)$
Wild-DIBE	$4n+2$	$3n+5$	5	DLin (any $k-$MDDH)	Full standard	$O(q_k)$

Attribute-Based Encryption

Name	$\|pk\|$	$\|sk\|$	$\|C\|$	pairing	exp $\mathbb{G}$	exp $\mathbb{G}_t$	Reduction Loss
[OT10]	$4U+2$	$3U+3$	$7m+5$	$7m+5$	0	m	$O(q_k)$
[LW12]	$24U+12$	$6U+6$	$6m+6$	$6m+9$	0	m	$O(q_k)$
[CGW15]	$6UR+12$	$3UR+3$	$3m+3$	6	$6m$	0	$O(q_k)$
[Att16] scheme 10	$6UR+12$	$3UR+6$	$3m+6$	9	$6m$	0	$O(q_k)$
[Att16] scheme 13	$96(M+TR)^2+log(UR)$	$3UR+6$	$3m+6$	9	$6m$	0	$O(q_k)$
Our DNF-ABE	$4U+2$	$3U+3$	$3k+2$	13	0	0	$O(q_k)$

Conclusion

- Another IBE related primitive
  - However it can be tightly linked to the others
  - So any progress on DIBE should lead to progress to the other primitive

- Can DIBE be achieved in a Post Quantum world?
- How to avoid the DNF limitation for ABE

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Thank you

Any questions?

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