

# 1 SchemeHIBME

This scheme is applicable to symmetric and asymmetric groups of prime orders.

## 1.1 Setup( $l$ ) $\rightarrow$ ( $mpk, msk$ )

$g \leftarrow 1_{\mathbb{G}_1}$   
 generate  $\alpha, b_1, b_2 \in \mathbb{Z}_r$  randomly  
 generate  $s_1, s_2, \dots, s_l, a_1, a_2, \dots, a_l \in \mathbb{Z}_r$  randomly  
 generate  $g_2, g_3 \in \mathbb{G}_2$  randomly  
 generate  $h_1, h_2, \dots, h_l \in \mathbb{G}_2$  randomly (Note that the indexes in implementations are 1 smaller than those in theory)  
 $H_1 : \mathbb{Z}_r \rightarrow \mathbb{G}_1$   
 $H_2 : \mathbb{Z}_r \rightarrow \mathbb{G}_2$   
 $\hat{H} : \mathbb{G}_T \rightarrow \{0, 1\}^\lambda$   
 $g_1 \leftarrow g^\alpha$   
 $A \leftarrow e(g_1, g_2)$   
 $\bar{g} \leftarrow g^{b_1}$   
 $\tilde{g} \leftarrow g^{b_2}$   
 $\bar{g}_3 \leftarrow g_3^{\frac{1}{b_1}}$   
 $\tilde{g}_3 \leftarrow g_3^{\frac{1}{b_2}}$   
 $mpk \leftarrow (g, g_1, g_2, g_3, \bar{g}, \tilde{g}, \bar{g}_3, \tilde{g}_3, h_1, h_2, \dots, h_l, H_1, H_2, \hat{H}, A)$   
 $msk \leftarrow (g_2^\alpha, b_1, b_2, s_1, s_2, \dots, s_l, a_1, a_2, \dots, a_l)$   
**return** ( $mpk, msk$ )

## 1.2 EKGen( $ID_k$ ) $\rightarrow$ $ek_{ID_k}$

$A_k \leftarrow \prod_{j=1}^k a_j$   
 $ek_{1,i} \leftarrow H_1(I_i)^{s_i A_k}, \forall i \in \{1, 2, \dots, k\}$   
 $ek_{2,i} \leftarrow s_{k+i} A_k, \forall i \in \{1, 2, \dots, l-k\}$   
 $ek_3 \leftarrow (a_{k+1}, a_{k+2}, \dots, a_l)$   
 $ek_{ID_k} \leftarrow (ek_1, ek_2, ek_3)$   
**return**  $ek_{ID_k}$

## 1.3 DerivedEKGen( $ek_{ID_{k-1}}, ID_k$ ) $\rightarrow$ $ek_{ID_k}$

$ek'_{1,i} \leftarrow ek_{1,i}^{a_k}, \forall i \in \{1, 2, \dots, k-1\}$   
 $ek'_{1,k} \leftarrow H_1(I_k)^{ek_{2,1} a_k}$   
 $ek'_1 \leftarrow ek'_1 || \langle ek'_{1,k} \rangle$   
 $ek'_{2,i} \leftarrow ek_{2,i} \cdot a_k, \forall i \in \{2, 3, \dots, l-k+1\}$   
 $ek'_3 \leftarrow (a_{k+1}, a_{k+2}, \dots, a_l)$   
 $ek_{ID_k} \leftarrow (ek'_1, ek'_2, ek'_3)$   
**return**  $ek_{ID_k}$

#### 1.4 DKGen( $ID_k$ ) $\rightarrow dk_{ID_k}$

generate  $r \in \mathbb{Z}_r$  randomly

$$HI \leftarrow h_1^{I_1} h_2^{I_2} \cdots h_k^{I_k}$$

$$a_0 \leftarrow g_2^{\frac{\alpha}{b_1}} \cdot HI^{\frac{r}{b_1}} \cdot \tilde{g}_3^r$$

$$a_1 \leftarrow g_2^{\frac{\alpha}{b_2}} \cdot HI^{\frac{r}{b_2}} \cdot \tilde{g}_3^r$$

$$A_k \leftarrow \prod_{j=1}^k a_j$$

$$dk_1 \leftarrow (a_0, a_1, g^r, h_{k+1}^{\frac{r}{b_1}}, h_{k+2}^{\frac{r}{b_1}}, \dots, h_l^{\frac{r}{b_1}}, h_{k+1}^{\frac{r}{b_2}}, h_{k+2}^{\frac{r}{b_2}}, \dots, h_l^{\frac{r}{b_2}}, h_{k+1}^{b_1^{-1}}, h_{k+2}^{b_1^{-1}}, \dots, h_l^{b_1^{-1}}, h_{k+1}^{b_2^{-1}}, h_{k+2}^{b_2^{-1}}, \dots, h_l^{b_2^{-1}}, HI^{\frac{1}{b_1}}, HI^{\frac{1}{b_2}})$$

$$dk_{2,i} \leftarrow H_2(I_i)^{s_i A_k}, \forall i \in \{1, 2, \dots, k\}$$

$$dk_{3,i} \leftarrow s_{k+i} A_k, \forall i \in \{1, 2, \dots, l-k\}$$

$$dk_4 \leftarrow (a_{k+1}, a_{k+2}, \dots, a_l)$$

$$dk_{ID_k} \leftarrow (dk_1, dk_2, dk_3, dk_4)$$

**return**  $dk_{ID_k}$

#### 1.5 DerivedDKGen( $dk_{ID_{k-1}}, ID_k$ ) $\rightarrow dk_{ID_k}$

generate  $t \in \mathbb{Z}_r$  randomly

$$a'_0 \leftarrow a_0 \cdot c_{0,k}^{I_k} \cdot (f_0 \cdot d_{0,k}^{I_k} \cdot \tilde{g}_3)^t$$

$$a'_1 \leftarrow a_1 \cdot c_{1,k}^{I_k} \cdot (f_1 \cdot d_{1,k}^{I_k} \cdot \tilde{g}_3)^t$$

$$dk'_1 \leftarrow (a'_0, a'_1, b \cdot g^t, c_{0,k+1} \cdot d_{0,k+1}^t, c_{0,k+2} \cdot d_{0,k+2}^t, \dots, c_{0,l} \cdot d_{0,l}^t, c_{1,k+1} \cdot d_{1,k+1}^t, c_{1,k+2} \cdot d_{1,k+2}^t, \dots, c_{1,l} \cdot d_{1,l}^t, d_{0,k+1}, d_{0,k+2}, \dots, d_{0,l}, d_{1,k+1}, d_{1,k+2}, \dots, d_{1,l}, f_0 \cdot c_{0,k}^{I_k}, f_1 \cdot c_{1,k}^{I_k})$$

$$dk'_{2,i} \leftarrow dk_{2,i}^{a_k}, \forall i \in \{1, 2, \dots, k-1\}$$

$$dk'_{2,k} \leftarrow H_2(I_k)^{dk_{3,1} a_k}$$

$$dk'_2 \leftarrow dk'_{2,k} \parallel \langle dk'_{2,k} \rangle$$

$$dk'_{3,i} \leftarrow dk_{3,i} \cdot a_k, \forall i \in \{2, 3, \dots, l-k+1\}$$

$$dk'_4 \leftarrow (a_{k+1}, a_{k+2}, \dots, a_l)$$

$$dk_{ID_k} \leftarrow (dk'_1, dk'_2, dk'_3, dk'_4)$$

**return**  $dk_{ID_k}$

#### 1.6 Enc( $ek_{ID_S}, ID_{Rev}, M$ ) $\rightarrow CT$

generate  $s_1, s_2, \eta \in \mathbb{Z}_r$  randomly

$$T \leftarrow A^{s_1+s_2}$$

**if**  $m = n$  **then**

$$K \leftarrow \prod_{i=1}^n e(g^\eta \cdot ek_{1,i}, H_2(I'_i))$$

**else if**  $m > n$  **then**

$$A_n \leftarrow \prod_{i=1}^n a_i$$

$$B_n^m \leftarrow \prod_{i=n+1}^m a_i$$

$$K \leftarrow (\prod_{i=1}^n e(ek_{1,i}, H_2(I'_i)) \cdot \prod_{i=n+1}^m e(H_1(I_n), H_2(I'_i))^{s_i A_n})^{B_n^m} \cdot e(g^\eta, \prod_{i=1}^m H_2(I'_i))$$

**else if**  $m < n$  **then**

$K \leftarrow \prod_{i=1}^m e(ek_{1,i}, H_2(I'_i)) \prod_{i=m+1}^n e(ek_{1,i}, H_2(I'_m)) e(g^\eta, \prod_{i=1}^m H_2(I'_i))$   
**end if**  
 $C_1 \leftarrow M \oplus \hat{H}(T) \oplus \hat{H}(K)$   
 $C_2 \leftarrow \bar{g}^{s_1}$   
 $C_3 \leftarrow \tilde{g}^{s_2}$   
 $C_4 \leftarrow (h_1^{I_1} h_2^{I_2} \dots h_n^{I_n} \cdot g_3)^{s_1+s_2}$   
 $C_5 \leftarrow g^\eta$   
 $CT \leftarrow (C_1, C_2, C_3, C_4, C_5)$   
**return**  $CT$

### 1.7 Dec( $dk_{ID_R}, ID_{Rev}, ID_{Snd}, CT$ ) $\rightarrow M$

$T' = \frac{e(dk_{1,3}, C_4)}{e(C_2, dk_{1,1})e(C_3, dk_{1,2})}$   
**if**  $m = n$  **then**  
 $K' \leftarrow \prod_{i=1}^n e(H_1(I_i), dk_{2,i}) \cdot e(C_5, \prod_{i=1}^n H_2(I'_i))$   
**else if**  $m > n$  **then**  
 $K' \leftarrow \prod_{i=1}^n e(H_1(I_i), dk_{2,i}) \cdot \prod_{i=n+1}^m e(H_1(I_n), dk_{2,i}) \cdot e(C_5, \prod_{i=1}^m H_2(I'_i))$   
**else if**  $m < n$  **then**  
 $A_m \leftarrow \prod_{i=1}^m a_i$   
 $B_n^m \leftarrow \prod_{i=m+1}^n a_i$   
 $K' \leftarrow (\prod_{i=1}^m e(H_1(I_i), dk_{2,i}) \cdot \prod_{i=m+1}^n e(H_1(I_i), H_2(I'_m))^{s_i A_m})^{B_m^n} \cdot e(C_5, \prod_{i=1}^m H_2(I'_i))$   
**end if**  
 $M \leftarrow C_1 \oplus \hat{H}(T') \oplus \hat{H}(K')$   
**return**  $M$