

# 1 SchemeIBBME

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

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

generate  $g, v \in \mathbb{G}_1$  randomly  
generate  $h \in \mathbb{G}_2$  randomly  
generate  $\vec{r}_1 = (r_{1,0}, r_{1,1}, \dots, r_{1,l}) \in \mathbb{Z}_r^{l+1}$  randomly  
generate  $\vec{r}_2 = (r_{2,0}, r_{2,1}, \dots, r_{2,l}) \in \mathbb{Z}_r^{l+1}$  randomly  
generate  $t_1, t_2, \beta_1, \beta_2, \alpha, \rho, b, \tau \in \mathbb{Z}_r$  randomly  
 $\vec{r} \leftarrow (r_0, r_1, \dots, r_l) = \vec{r}_1 + b\vec{r}_2 = (r_{1,0} + br_{2,0}, r_{1,1} + br_{2,1}, \dots, r_{1,l} + br_{2,l})$   
 $t \leftarrow t_1 + bt_2$   
 $\beta \leftarrow \beta_1 + b\beta_2$   
 $\vec{R} \leftarrow g^{\vec{r}} = (g^{r_0}, g^{r_1}, \dots, g^{r_l})$   
 $T \leftarrow g^t$   
 $H_0 : \{0, 1\}^* \rightarrow \mathbb{G}_2$   
 $H_1 : \{0, 1\}^* \rightarrow \mathbb{G}_1$   
 $H_2 : \{0, 1\}^* \rightarrow \mathbb{Z}_r$   
 $H_3 : \mathbb{G}_T \rightarrow \mathbb{Z}_r$   
 $mpk \leftarrow (v, v^\rho, g, g^b, \vec{R}, T, e(g, h)^\beta, h, h^{\vec{r}_1}, h^{\vec{r}_2}, h^{t_1}, h^{t_2}, g^{\tau\beta}, h^{\tau\beta_1}, h^{\tau\beta_2}, h^{1/\tau}, H_0, H_1, H_2, H_3)$   
 $msk \leftarrow (h^{\beta_1}, h^{\beta_2}, \alpha, \rho)$   
**return** (*mpk*, *msk*)

## 1.2 EKGen(*id*<sup>\*</sup>) $\rightarrow$ *ek*<sub>*id*<sup>\*</sup></sub>

$ek_{id^*} \leftarrow H_1(id^*)^\alpha$   
**return** *ek*<sub>*id*<sup>\*</sup></sub>

## 1.3 DKGen(*id*) $\rightarrow$ *dk*<sub>*id*</sub>

generate  $z \in \mathbb{Z}_r$  randomly  
generate  $rtags = (rtag_1, rtag_2, \dots, rtag_l) \in \mathbb{Z}_r^l$  randomly  
 $dk_1 \leftarrow H_0(id)^\rho$   
 $dk_2 \leftarrow H_0(id)^\alpha$   
 $dk_3 \leftarrow H_0(id)$   
 $dk_4 \leftarrow h^{\beta_1}(h^{t_1})^z$   
 $dk_5 \leftarrow h^{\beta_2}(h^{t_2})^z$   
 $dk_6 \leftarrow h^z$   
 $dk_{7,j} \leftarrow ((h^{t_1})^{rtag_j} h^{r_{1,j}} / (h^{r_{1,0}})^{H_2(id)^j})^z, \forall j \in \{1, 2, \dots, l\}$   
 $dk_{8,j} \leftarrow ((h^{t_2})^{rtag_j} h^{r_{2,j}} / (h^{r_{2,0}})^{H_2(id)^j})^z, \forall j \in \{1, 2, \dots, l\}$   
 $dk_{id} \leftarrow (dk_1, dk_2, \dots, dk_8, rtags)$   
**return** *dk*<sub>*id*</sub>

## 1.4 Enc(*S*, *ek*<sub>*id*<sup>\*</sup>, *m*) $\rightarrow$ *ct*</sub>

Compute  $y_0, y_1, y_2, \dots, y_n$  that satisfy  $\forall x \in \mathbb{Z}_r$ , we have  $F(x) = \prod_{id_j \in S} (x -$

$$H_2(id_j)) = y_0 + \sum_{i=1}^n y_i x^i$$

$\vec{y} \leftarrow (y_0, y_1, \dots, y_n, y_{n+1}, y_{n+2}, \dots, y_l) = (y_0, y_1, \dots, y_n, 0, 0, \dots, 0)$   
 generate  $s, d_2, ctag \in \mathbb{Z}_r$  randomly  
 $C_0 \leftarrow m \cdot e(g, h)^{\beta s}$   
 $C_1 \leftarrow g^s$   
 $C_2 \leftarrow g^{bs}$   
 $C_3 \leftarrow \left( T^{ctag} \prod_{i=0}^n (g^{r_i})^{y_i} \right)^{d_2 s}$   
 $C_4 \leftarrow v^s$   
 $V_{id_i} \leftarrow H_3(e(H_0(id_i), ek_{id^*} \cdot g^{bs} \cdot v^{\rho s})), \forall id_i \in S$   
 Compute  $\vec{b} \leftarrow (b_0, b_1, b_2, \dots, b_n)$  that satisfy  $\forall y \in \mathbb{Z}_r$ , we have  $g(y) = \prod_{V_{id_k} \in V_{id}} (y -$   
 $V_{id_k}) + d_2 = b_0 + \sum_{k=1}^n b_k y^k$   
 $ct \leftarrow (C_0, C_1, C_2, C_3, C_4, ctag, \vec{y}, \vec{b})$   
**return**  $ct$

### 1.5 Dec( $S, dk_{id_i}, id^*, ct$ ) $\rightarrow m$

$V(id_i) \leftarrow H_3(e(dk_{i,3}, C_2)e(dk_{i,2}, H_1(id^*))e(dk_{i,1}, C_4))$   
 $d_2 \leftarrow g(V_{id_i}) = b_0 + \sum_{j=1}^n b_j V_{id_i}^j$   
 $rtag \leftarrow \sum_{i=1}^l y_i rtags_i$   
**if**  $rtag = ctag$  **then**  
 $m \leftarrow \perp$   
**else**  
 $A \leftarrow e\left(C_1, \prod_{j=1}^l dk_{7,j}^{y_j}\right) e\left(C_2, \prod_{j=1}^l dk_{8,j}^{y_j}\right) / e(C_3^{1/d_2}, dk_6)$   
 $B \leftarrow e(C_1, dk_4) \cdot e(C_2, dk_5)$   
 $m \leftarrow C_0 \cdot A^{1/(rtag-ctag)} \cdot B^{-1}$   
**end if**  
**return**  $m$