Algorithm 1: Item Batch Activeness

Insert:

Input: An item a,current time t_{cur}

for $i = 1$ *to* k **do**

    $l_i[a] = H_i[a]\%n$;

    $cc[l_i[a]] = 2^s - 1$;

Return;

Query:

Input: An item a,current time t_{cur}

Output: Whether the item a showed up within the past time window

for $i = 1$ *to* k **do**

    $l_i[a] = H_i[a]\%n$;

    if $cc[l_i[a]] = 0$ **then**

        Return $False$;

Return $True$;

Refresh: $ptr = 0$;

while 1 **do**

    if $cc[ptr] > 0$ **then**

        $cc[ptr] = cc[ptr] - 1$;

    $ptr = (ptr + 1)\%n$;

    wait($\frac{T}{2^s-2}$);

Algorithm 2: Item Batch Cardinality

Insert:

Input: An item a,current time t_{cur}

for $i = 1$ *to* k **do**

    $l_i[a] = H_i[a]\%n$;

    $cc[l_i[a]] = 2^s - 1$;

Return;

Query:

Output: the cardinality of item batch

$u = 0$;

for $i = 1$ *to* n **do**

    if $cc[i] = 0$ **then**

        $u = u + 1$;

Return $-nln\frac{u}{n}$;

Refresh:

$ptr = 0$;

while 1 **do**

    if $cc[ptr] > 0$ **then**

        $cc[ptr] = cc[ptr] - 1$;

    $ptr = (ptr + 1)\%n$;

    wait($\frac{T}{2^s-2}$);

Algorithm 3: Item Batch Time Span

Insert:

Input: An item a,current time t_{cur}

for $i = 1$ *to* k **do**

    $l_i[a] = H_i[a]\%n$;

    $cc[l_i[a]] = 2^s - 1$;

    if $sc[l_i[a]] = 0$ **then**

        $sc[l_i[a]] = t_{cur}$

Return;

Query:

Input: An item a,current time t_{cur}

Output: the time span of item batch B_a

$t_{begin} = 0$;

for $i = 1$ *to* k **do**

    $l_i[a] = H_i[a]\%n$;

    $t_{begin} = max\{t_{begin}, sc[l_i[a]]\}$

Return $t_{cur} - t_{begin}$;

Refresh:

$ptr = 0$;

while 1 **do**

    if $cc[ptr] > 0$ **then**

        $cc[ptr] = cc[ptr] - 1$;

        if $cc[ptr] = 0$ **then**

            $sc[ptr] = 0$;

    $ptr = (ptr + 1)\%n$;

    wait($\frac{T}{2^s-2}$);

Algorithm 4: Item Batch Size

Insert:

Input: An item a,current time t_{cur}

for $i = 1$ *to* k **do**

    $l_i[a] = H_i[a]\%n$;

    $cc[l_i[a]] = 2^s - 1$;

    $sc[l_i[a]] = sc[l_i[a]] + 1$;

Return;

Query:

Input: An item a

Output: the size of item batch B_a,current time t_{cur}

$size = Infinity$;

for $i = 1$ *to* k **do**

    $l_i[a] = H_i[a]\%n$;

    $t_{begin} = min\{size, sc[l_i[a]]\}$

Return $size$;

Refresh:

$ptr = 0$;

while 1 **do**

    if $cc[ptr] > 0$ **then**

        $cc[ptr] = cc[ptr] - 1$;

        if $cc[ptr] = 0$ **then**

            $sc[ptr] = 0$;

    $ptr = (ptr + 1)\%n$;

    wait($\frac{T}{2^s-2}$);