PROTOCOL VERIFICATION IN THE COMPUTATIONAL MODEL

(using EasyCrypt)

NAXOS

$\mathcal{A}$ $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ $\mathcal{B}$

$esk_{\mathcal{A}} \xleftarrow{\$} \{0,1\}^{\lambda}$ $\qquad$ $X = g^{H_1(esk_{\mathcal{A}}, sk_{\mathcal{A}})}$ $\longrightarrow$

$esk_{\mathcal{B}} \xleftarrow{\$} \{0,1\}^{\lambda}$

$\longleftarrow$ $Y = g^{H_1(esk_{\mathcal{B}}, sk_{\mathcal{B}})}$

$$\mathcal{B}: \; K \leftarrow H_2(pk_{\mathcal{A}}^{H_1(esk_{\mathcal{B}}, sk_{\mathcal{B}})}, \; X^{sk_{\mathcal{B}}}, \; X^{H_1(esk_{\mathcal{B}}, sk_{\mathcal{B}})}, \; \mathcal{A}, \; \mathcal{B})$$

$$\mathcal{A}: \; K \leftarrow H_2(Y^{sk_{\mathcal{A}}}, \; pk_{\mathcal{B}}^{H_1(esk_{\mathcal{A}}, sk_{\mathcal{A}})}, \; Y^{H_1(esk_{\mathcal{A}}, sk_{\mathcal{A}})}, \; \mathcal{A}, \; \mathcal{B})$$

AKE PROTOCOLS

$\mathcal{A}$ $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ $\mathcal{B}$

$esk_{\mathcal{A}} \xleftarrow{\$} \{0,1\}^{\lambda}$ $\qquad$ $X = g^{H_1(esk_{\mathcal{A}}, sk_{\mathcal{A}})}$ $\longrightarrow$

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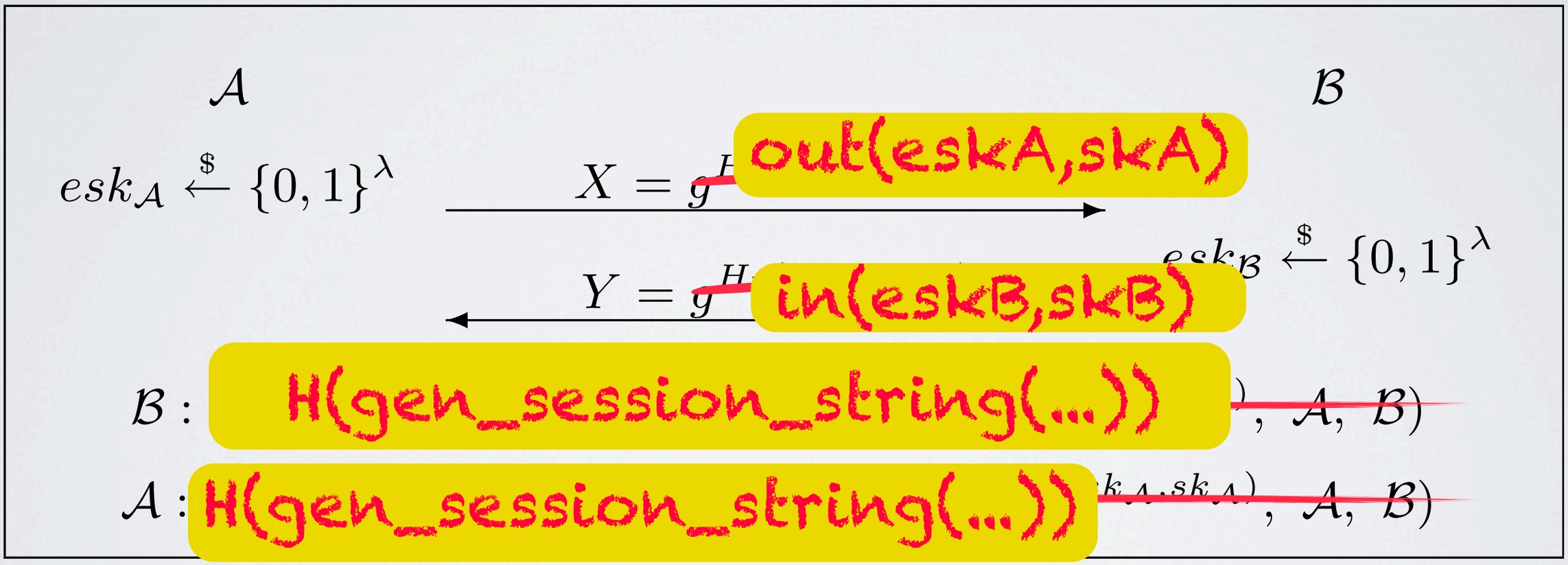
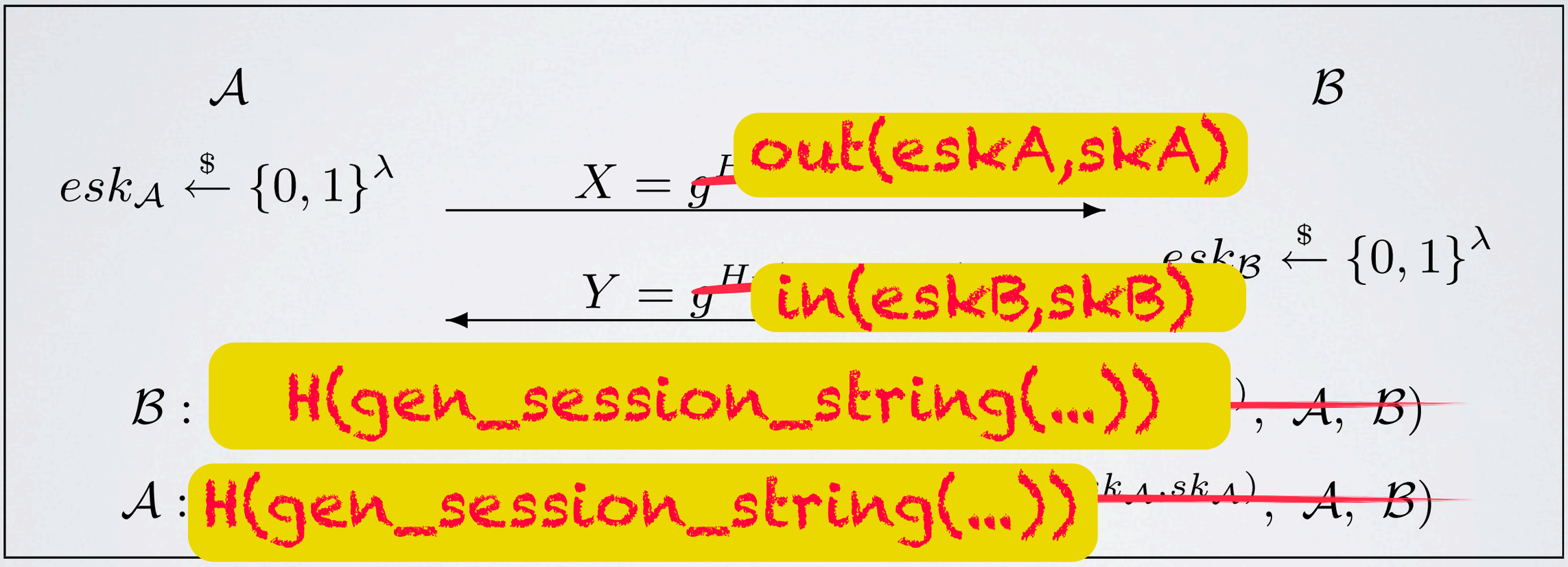
$\mathcal{B}: K \leftarrow H_2(pk_{\mathcal{A}}^{H_1(esk_{\mathcal{B}}, sk_{\mathcal{B}})}, X^{sk_{\mathcal{B}}}, X^{H_1(esk_{\mathcal{B}}, sk_{\mathcal{B}})}, \mathcal{A}, \mathcal{B})$

$\mathcal{A}: K \leftarrow H_2(Y^{sk_{\mathcal{A}}}, pk_{\mathcal{B}}^{H_1(esk_{\mathcal{A}}, sk_{\mathcal{A}})}, Y^{H_1(esk_{\mathcal{A}}, sk_{\mathcal{A}})}, \mathcal{A}, \mathcal{B})$

AKE PROTOCOLS



AKE PROTOCOLS



how much of the proof can we get away with without instantiating?

ORACLES

- KG() : public_key
- Init(A : part, B: part) : msg option
- Respond(B : part, A : part, X : msg) : msg option
- Complete(A:part, B:part, X:msg, Y:msg) : unit
- Hash(str : session_string) : session_key
- Corrupt(A : part) : private_key option
- EphKeyReveal(A : part, X : msg) : eph_key option
- KeyReveal(s : session_id) : session_key
- Test(s : session_id) : session_key

ORACLES (HASH, 4 LOC)

```
fun H(lam:session_string) : session_key = {
 var h : session_key = gen_session_key(0);
 if (!in_dom(lam, LH)) { LH[lam] = h; }
 return LH[lam];
}
```

ORACLES (INIT, ~10 LOC)

```
fun Init(A:part, B:part) : message option = {
  var x : eph_key = gen_eph_key(0);
  var a : secret_key;
  var X : message option = None;
  if (in_dom(A, skey) && in_dom(B, skey)){
   a = skey[A];
   X = Some(out_noclash(a, x));
   if (!in_dom((proj(X),A), seed)) {
    incomplete_sessions[(A,proj(X))] = (B,false);
    seed[(proj(X),A)] = x;
   }
   else
   {
    X = None;
   }
  }
  return X;}
```

ORACLES (KEYREVEAL, ~100 LOC)

```
fun KeyReveal(s : session_id) : session_key = {
  var A:part = fstpart(s);
  var B:part = sndpart(s);
  var X:message = fstmsg(s);
  var Y:message = sndmsg(s);
  var x : eph_key = seed[(X,A)];
  var B' : part = dummy_part;
  var Y' : message = dummy_msg;
  var eph_flagA : bool = false;
  var eph_flagB : bool = false;
  var A' : part = dummy_part;
  var X' : message = dummy_msg;
  var sstr : session_string = dummy_string;
  var ssskey : session_key = dummy_session_key;
  var matchb : bool = false;
  var h : session_key = dummy_session_key;
  var sidA, sidB : session_id;
  h = gen_session_key(0);
  if (in_dom((A,X), complete_sessions))
  { (* (A,_,X,_) is completed*)
    B' = session_part(complete_sessions[(A,X)]);
    Y' = session_msg(complete_sessions[(A,X)]);
    sidA = mk_sid(A, B', X, Y');
    eph_flagA = session_eph_flag(complete_sessions[(A,X)]);
    if ( B = B' && Y = Y')
    {(* B = B' /\ Y = Y'*)
    if (!in_dom((B,Y), complete_sessions))
     {(*B,_,Y,_ not complete*)
      if (! in_dom(sidA, tested_session))
      {(*Fresh*)
        complete_sessions[(A,X)] = mk_session_descr(B',Y',eph_flagA,true);
        sstr = gen_session_string_sid(sidA,skey,seed);
            (*sstr = gen_session_string(skey[A], x, B,Y);*)
            ssskey = iH(sstr, h);
      }
      else
      { (*not fresh*)
        ssskey = dummy_session_key;
      }
    }
  else
  { (* B,_,Y_ complete *)
      A' = session_part(complete_sessions[(B,Y)]);
      X' = session_msg(complete_sessions[(B,Y)]);
      sidB = mk_sid(B, A', Y, X');
      matchb = session_match( mk_sid (A, B', X,Y'),mk_sid(B,A',Y,X'));
```

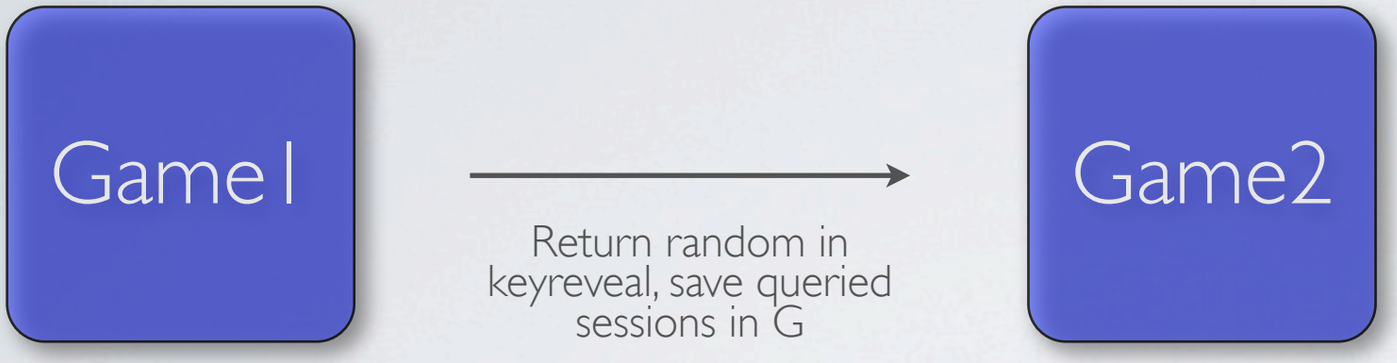
MAIN

```
fun Main () : bool = {
 var b' : bool;
 var tt : unit;
 complete_sessions = empty_map;  incomplete_sessions = empty_map;
 corrupt = empty_map;  pkey = empty_map;
 skey = empty_map;  LH  = empty_map;
 LHT  = empty_map;  seed  = empty_map;
 tested_session = empty_map;  G = empty_map;
 b = {0,1};
 b' = A();
 return (b = b');
}
```

GAME SEQUENCE

Game I

GAME SEQUENCE



GAME SEQUENCE

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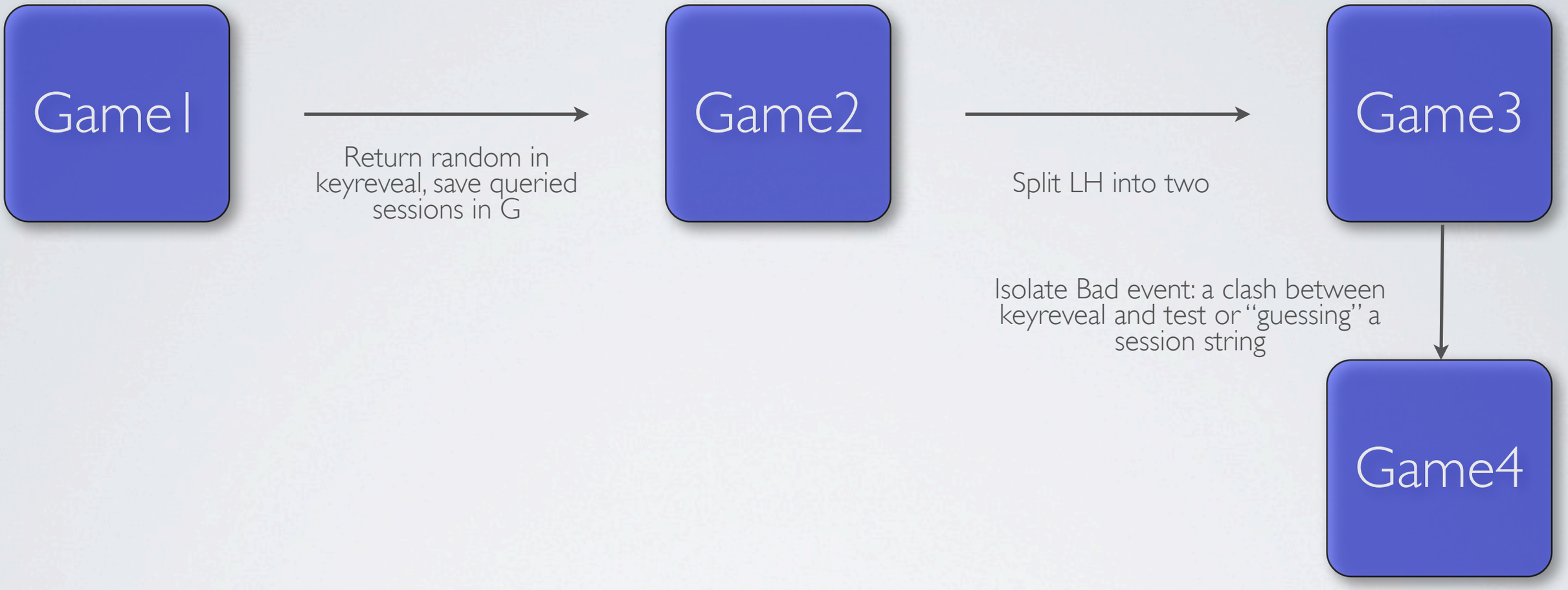

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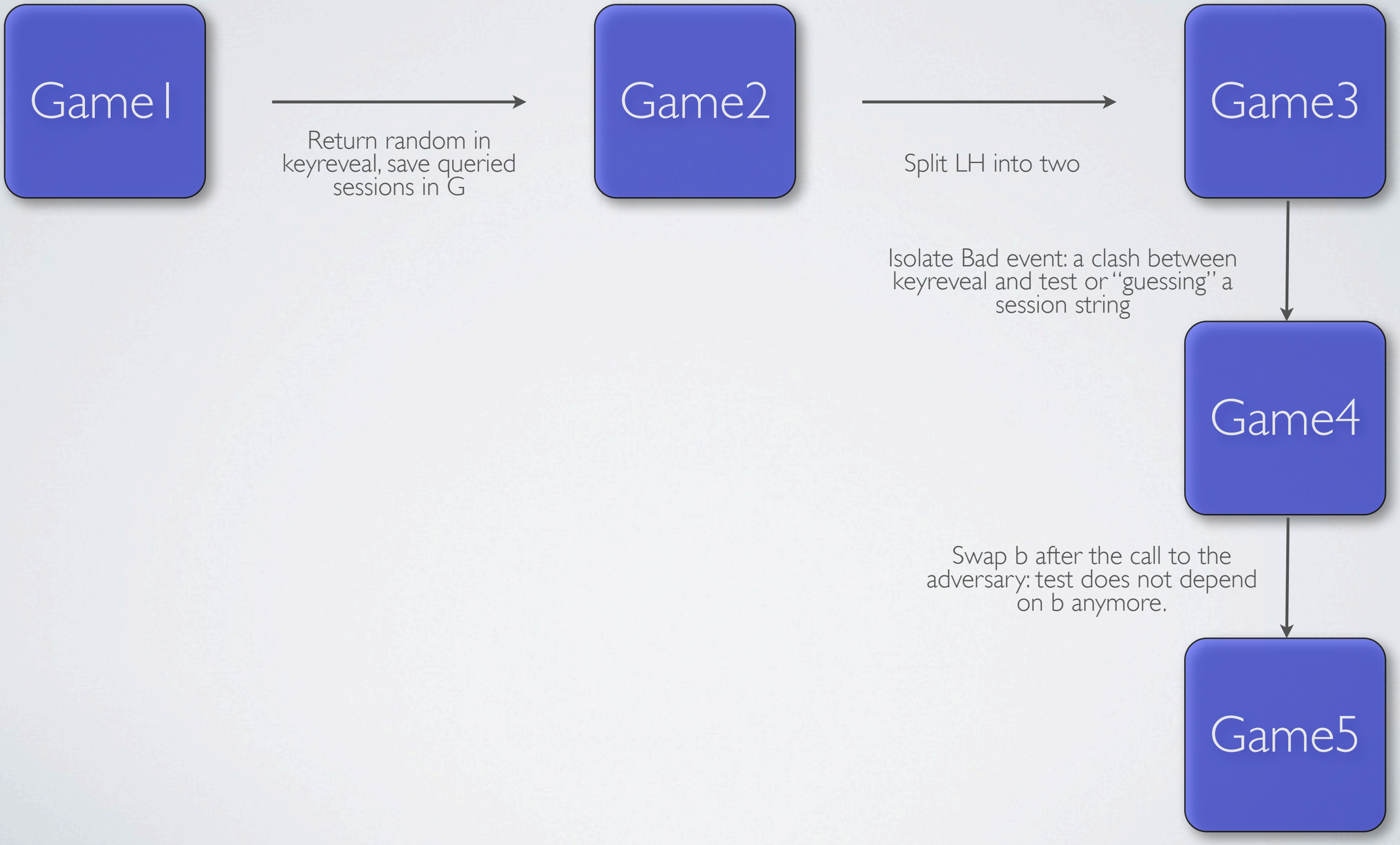

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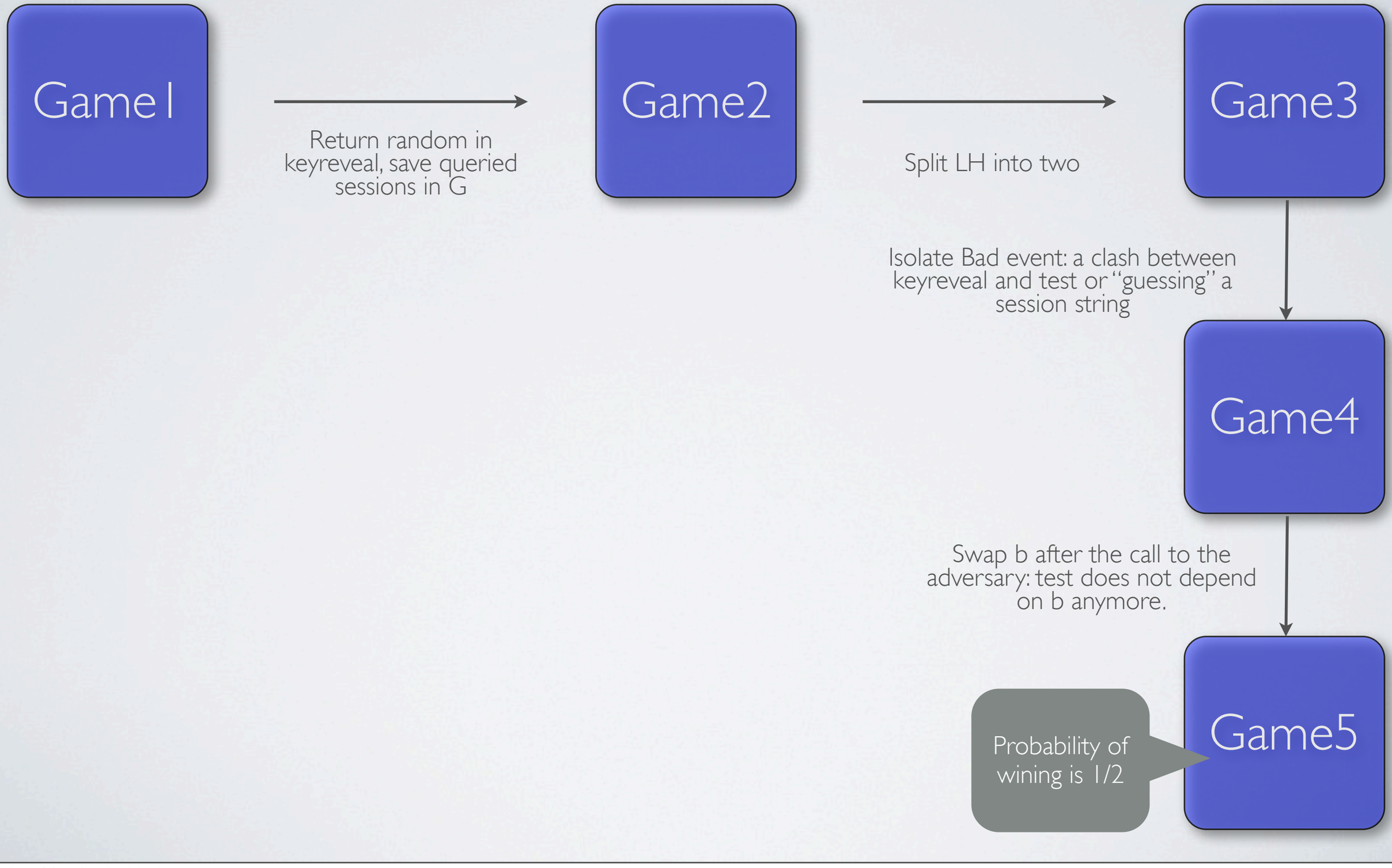

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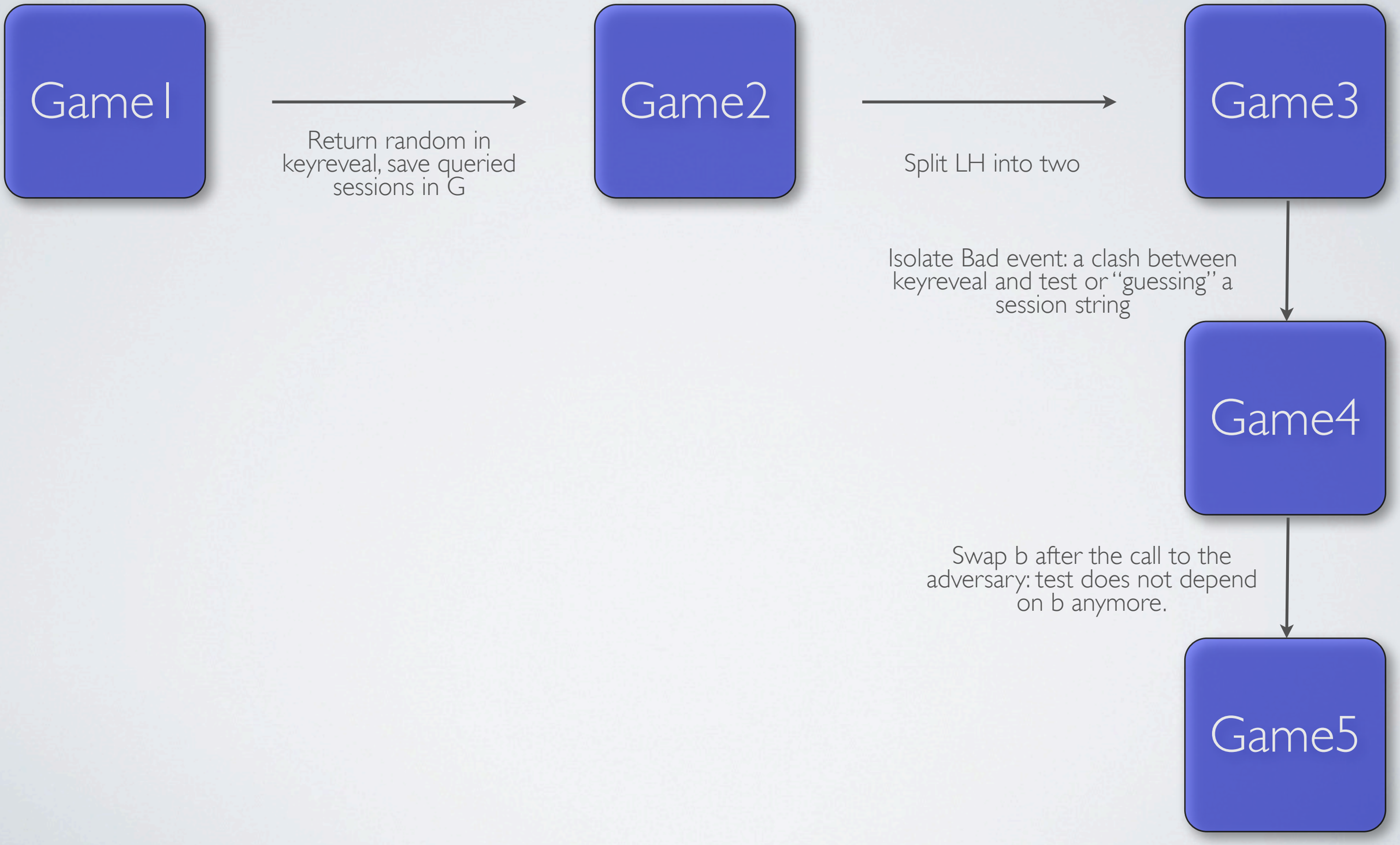

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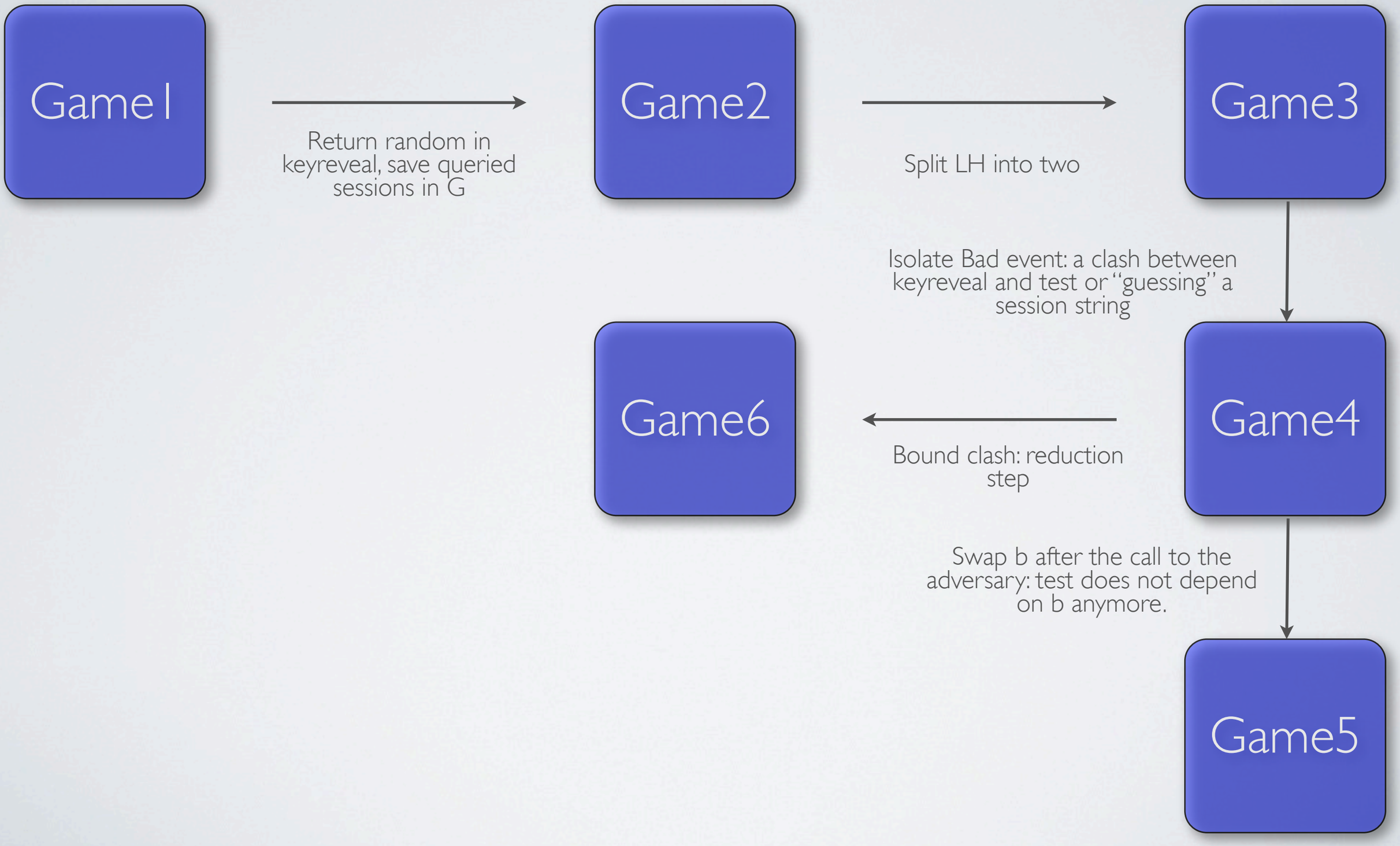

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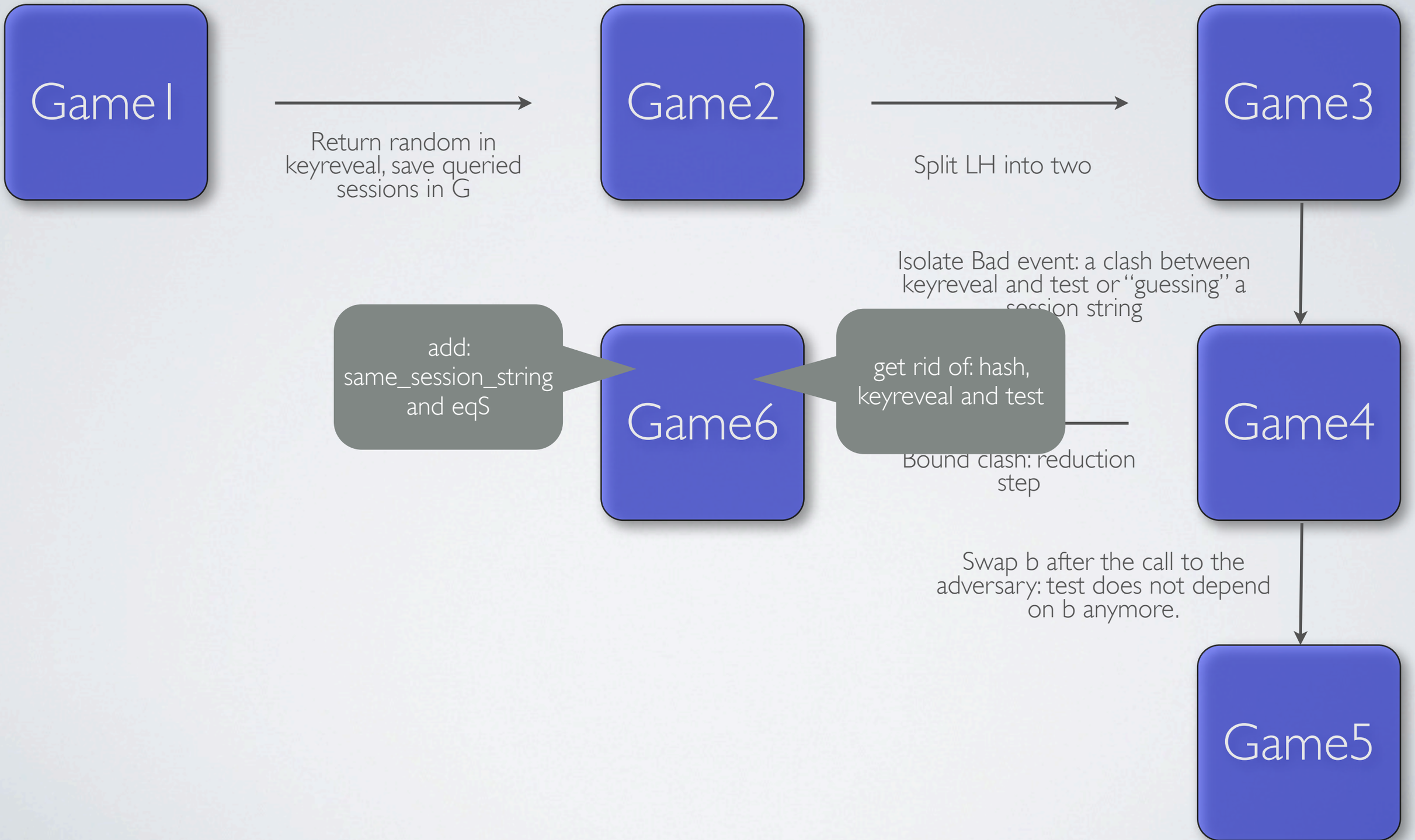

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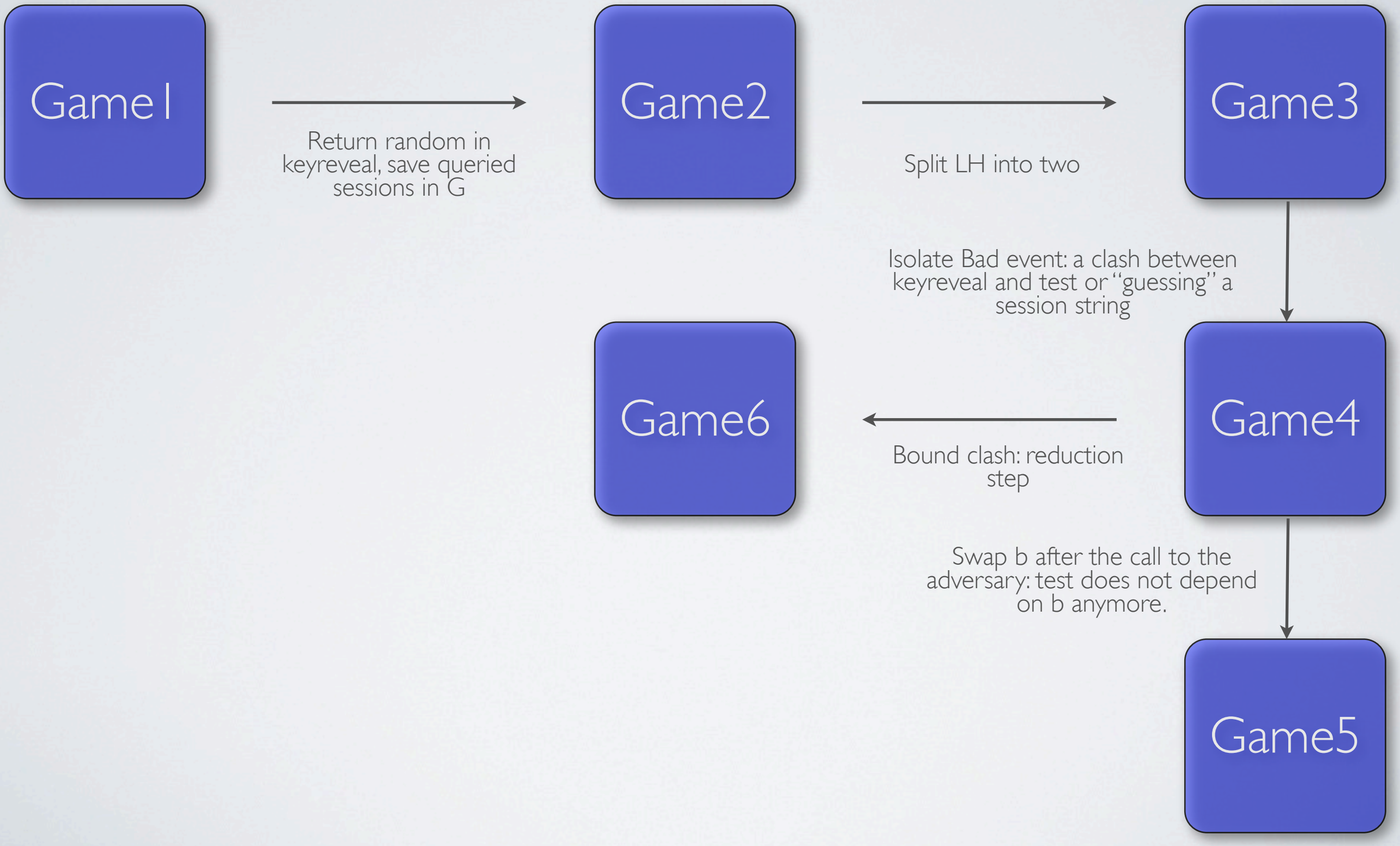

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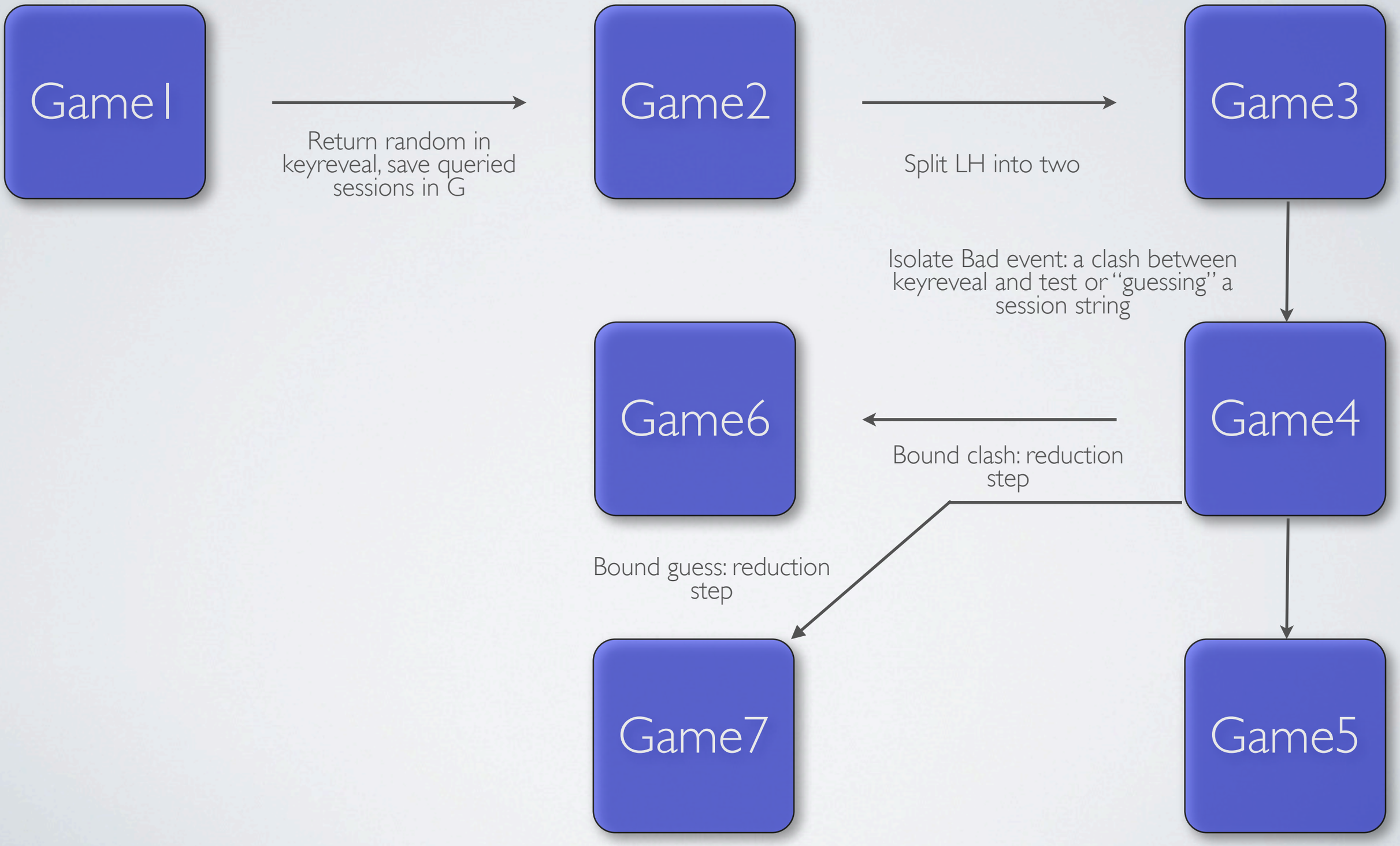

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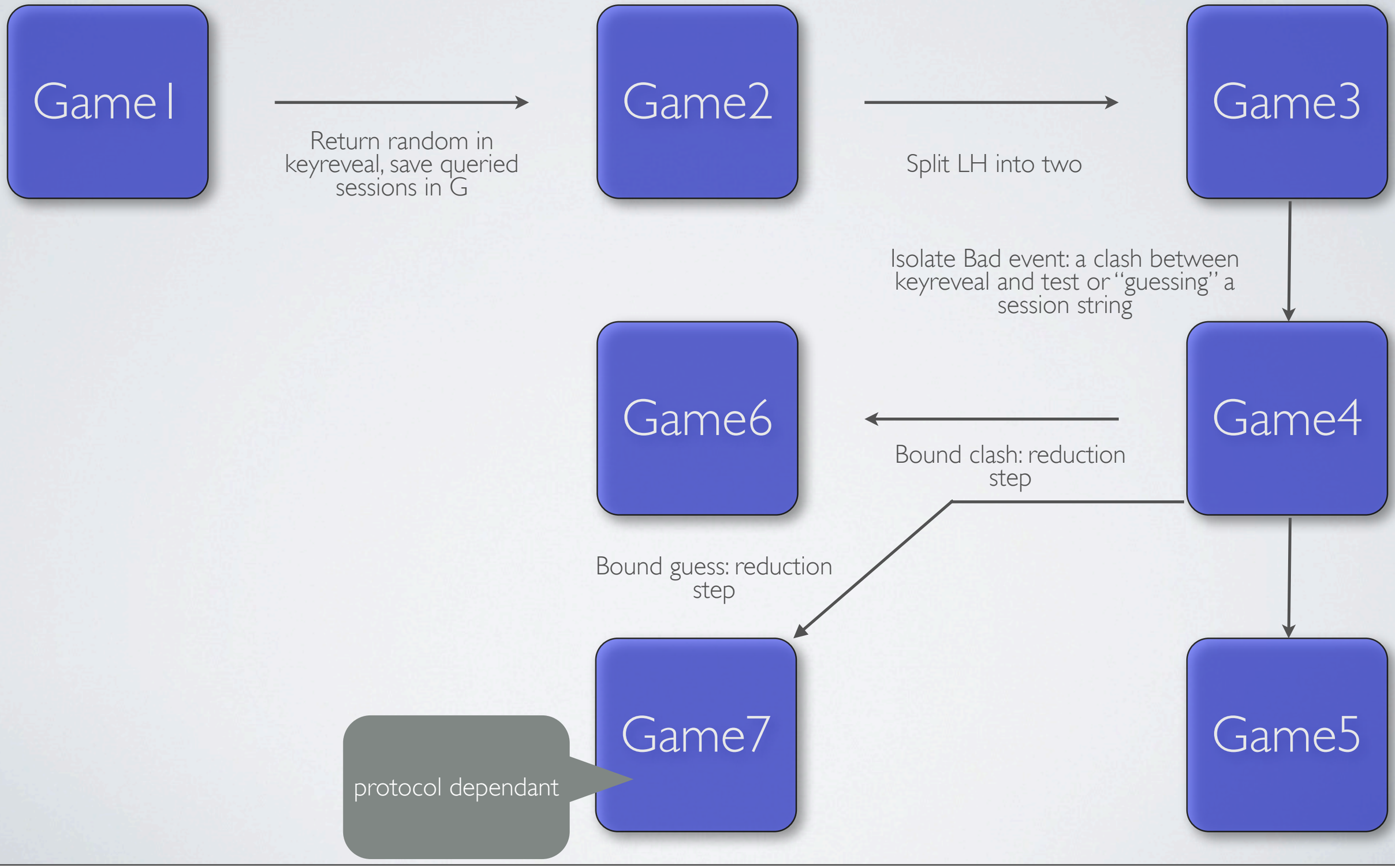

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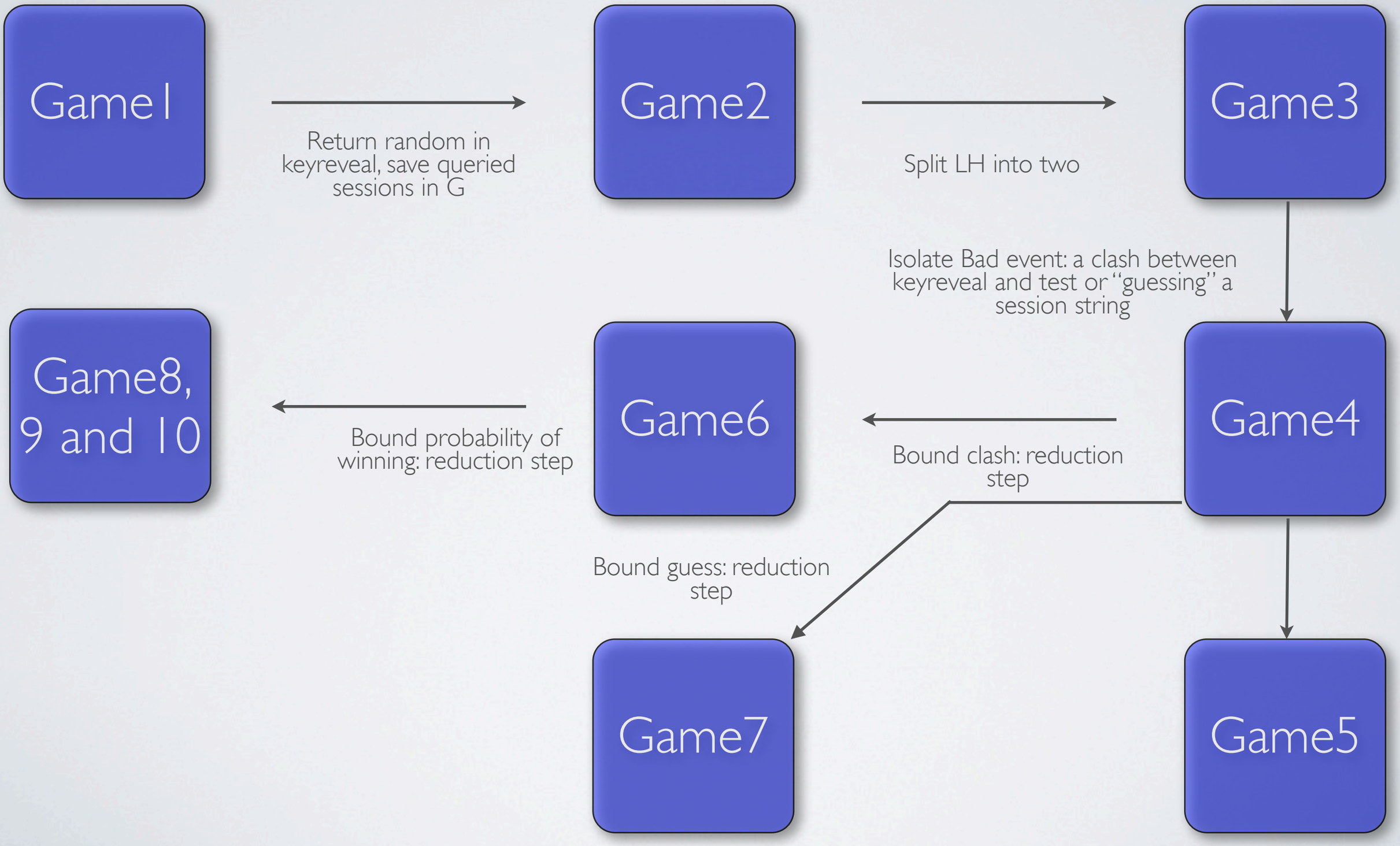

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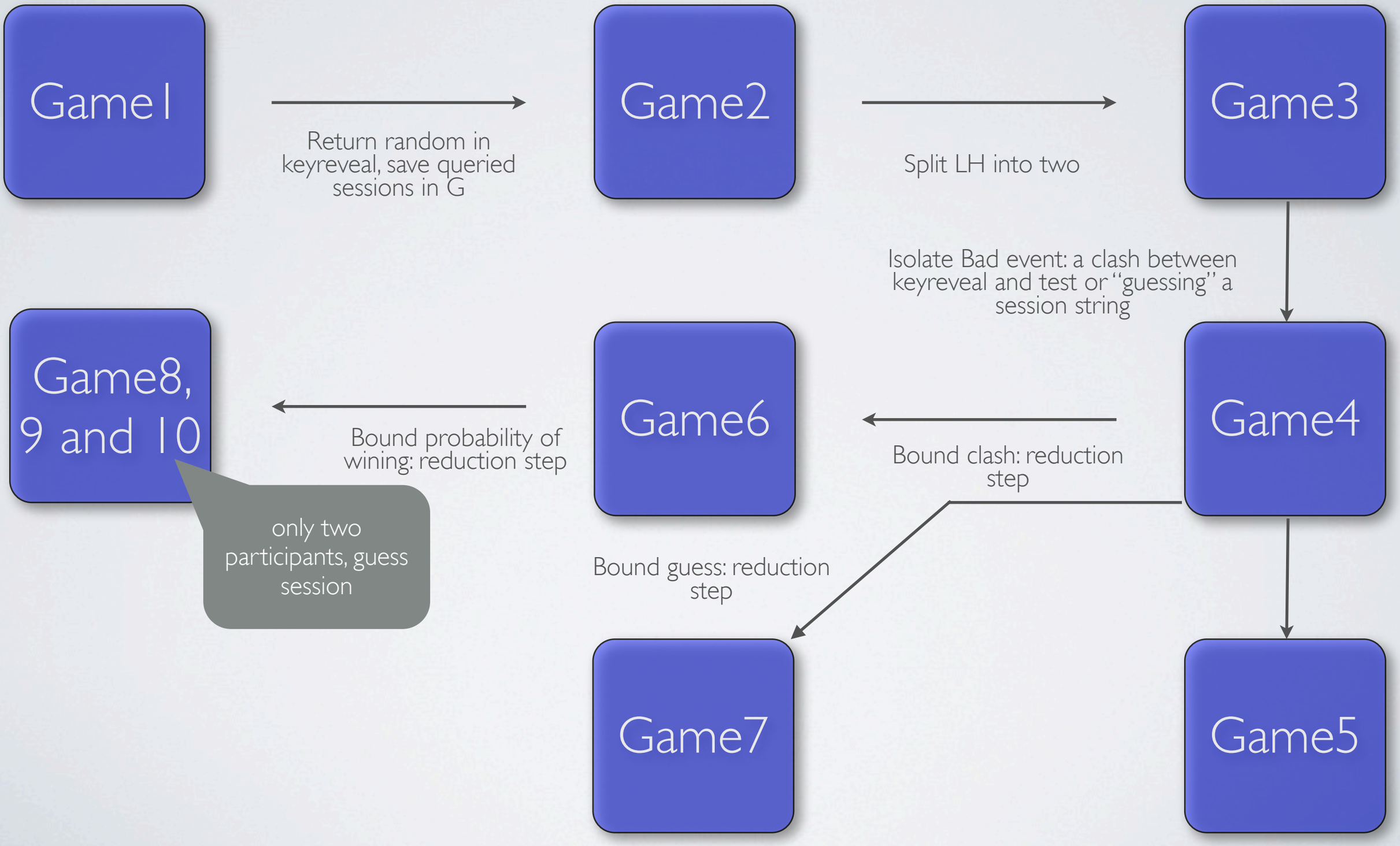

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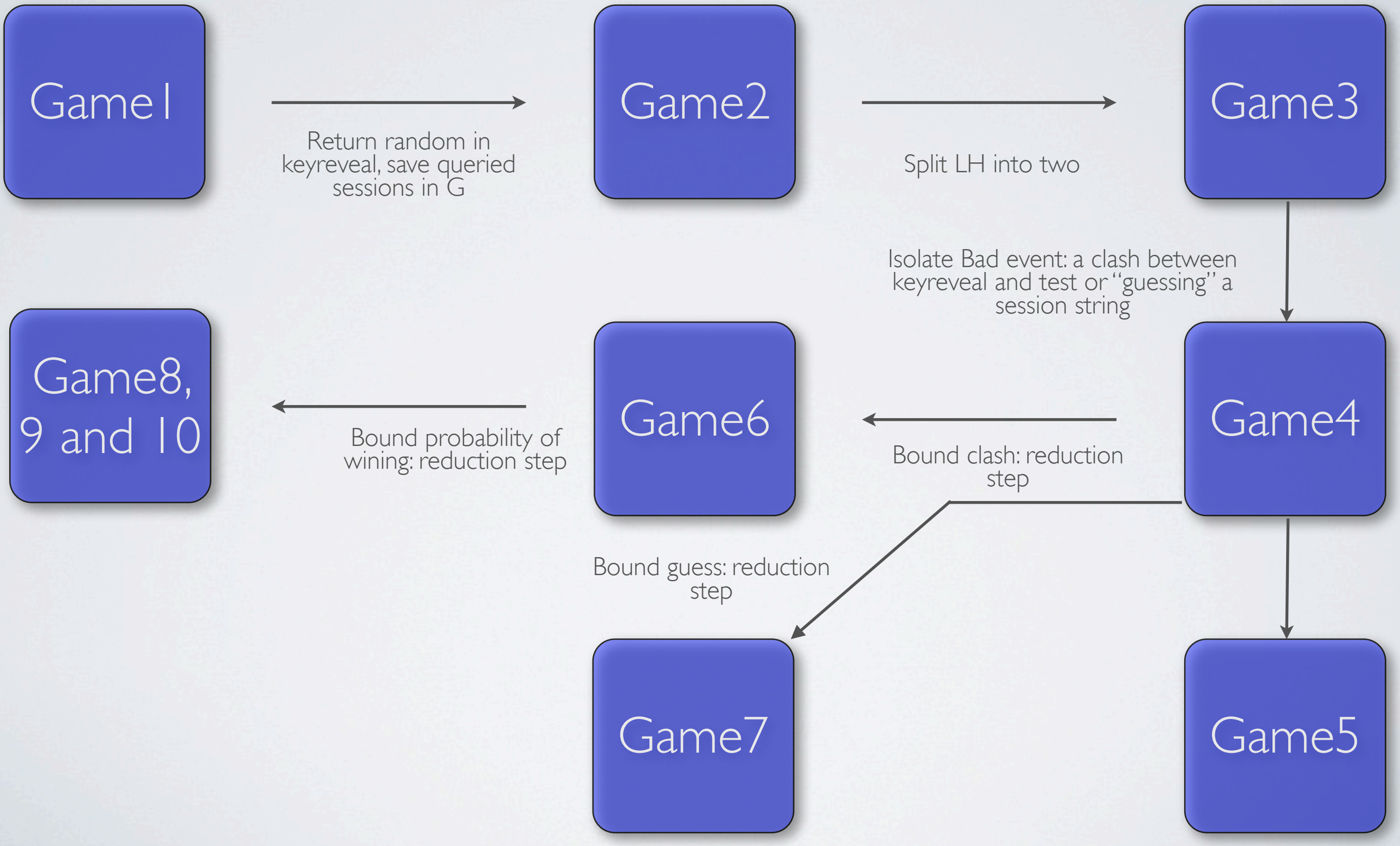

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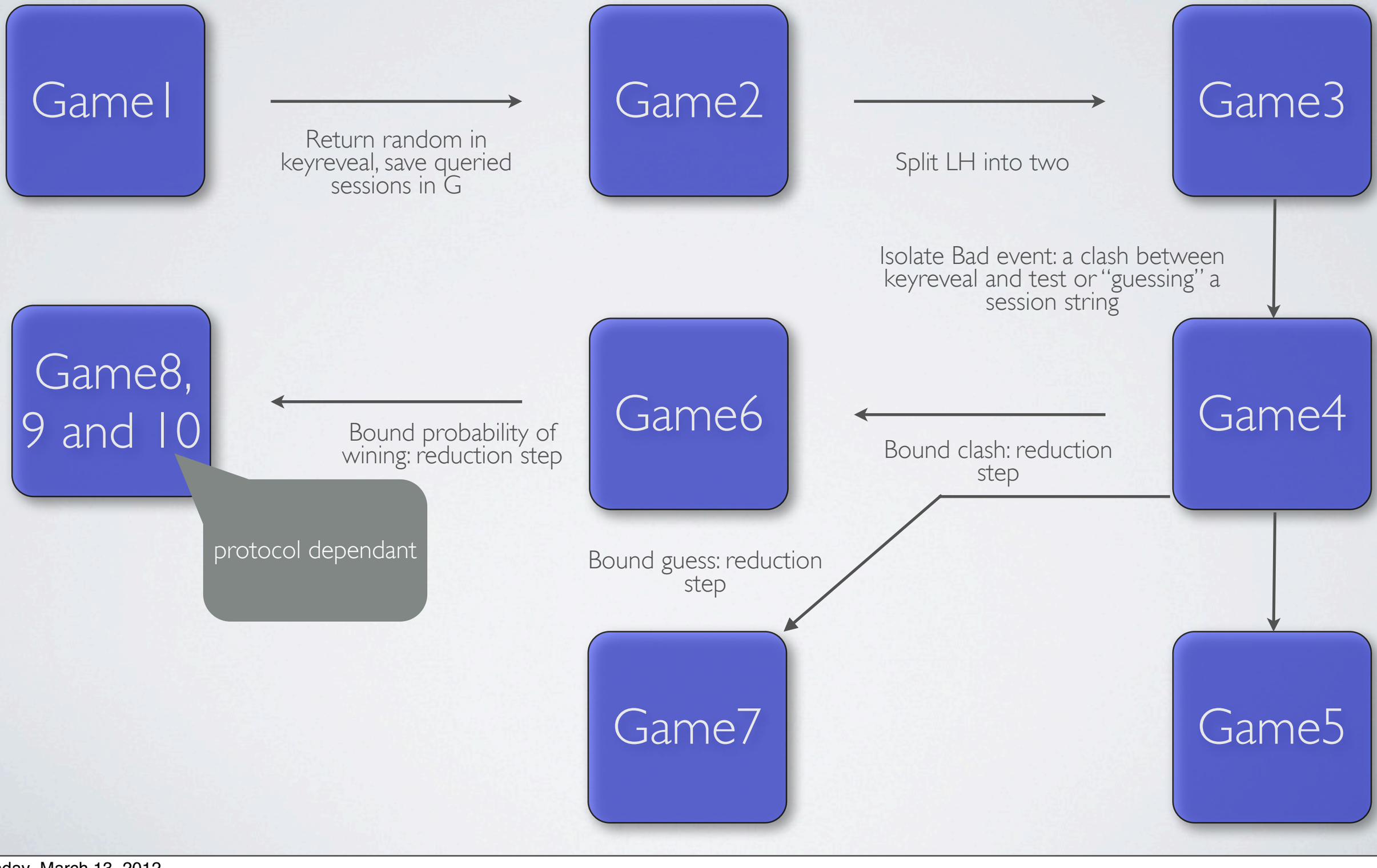

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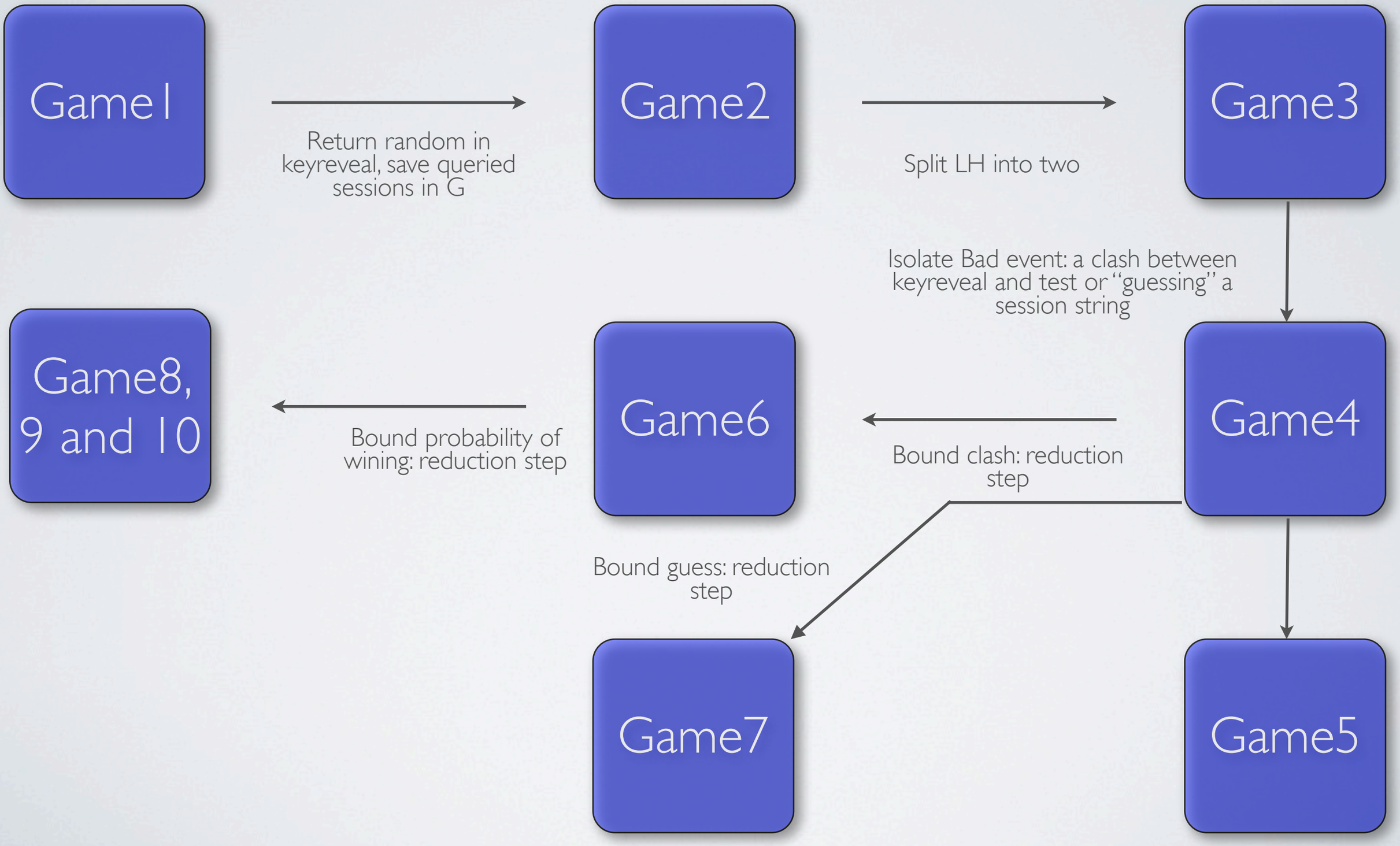

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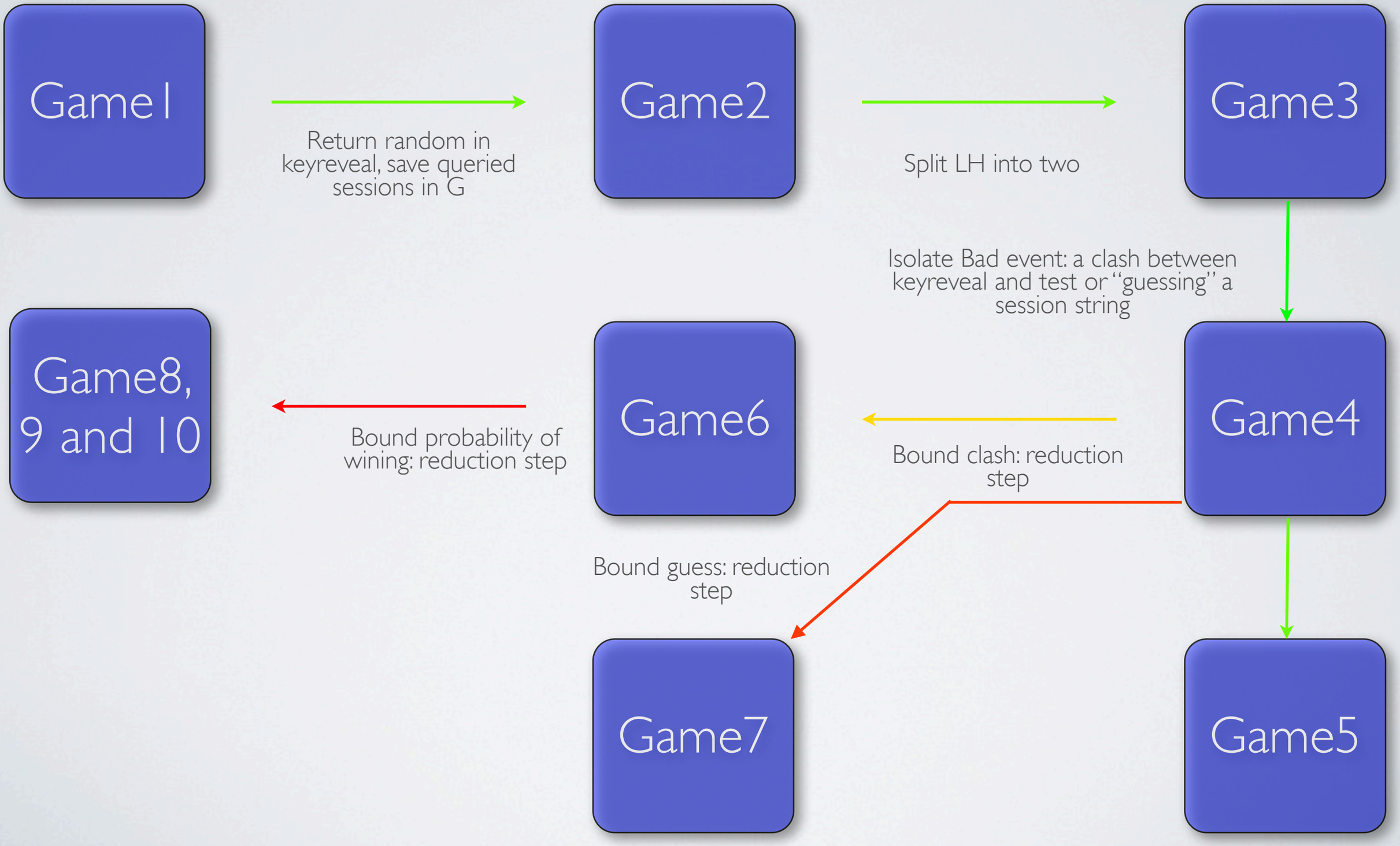

AN INVARIANT (STEP 1-2)

```
invariant1(LH{1},LH{2}) && invariant2(G{2}, LH{1}, skey{2}, seed
{2}) && invariant3(G{2},LH{1}, LH{2}, skey{2}, seed{2}) && ={b,
bad, complete_sessions, incomplete_sessions, corrupt, pkey, skey,
seed,  LHT, tested_session,s}
```

```
pred invariant1(...)= forall (str : session_string), in_dom
(str,LH2)  =>  (in_dom(str,LH1) && LH1[str] = LH2[str]

pred invariant2 (...) = forall (str : session_string, fer_sid :
session_id),(( findelse_g_abs(G2,str,skey2, seed2) <> None) =>
( in_dom(str,LH1) &&  LH1[str] = G2[proj(findelse_g_abs
(G2,str,skey2, seed2))]))

pred invariant3 (...) = forall (str : session_string), in_dom
(str,LH1) => ( in_dom(str, LH2)  || findelse_g_abs(G2,str,skey2,
seed2) <> None)
```

CHALLENGES

- Scaling: many proof obligations, too much branching.
- Deal with Successive reduction steps in a more succinct way.
- Identify common proof steps and prove them once and for all.
- Invariant inference.