NISC:
Non-Interactive Secure Computation

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- Dating for cryptographers

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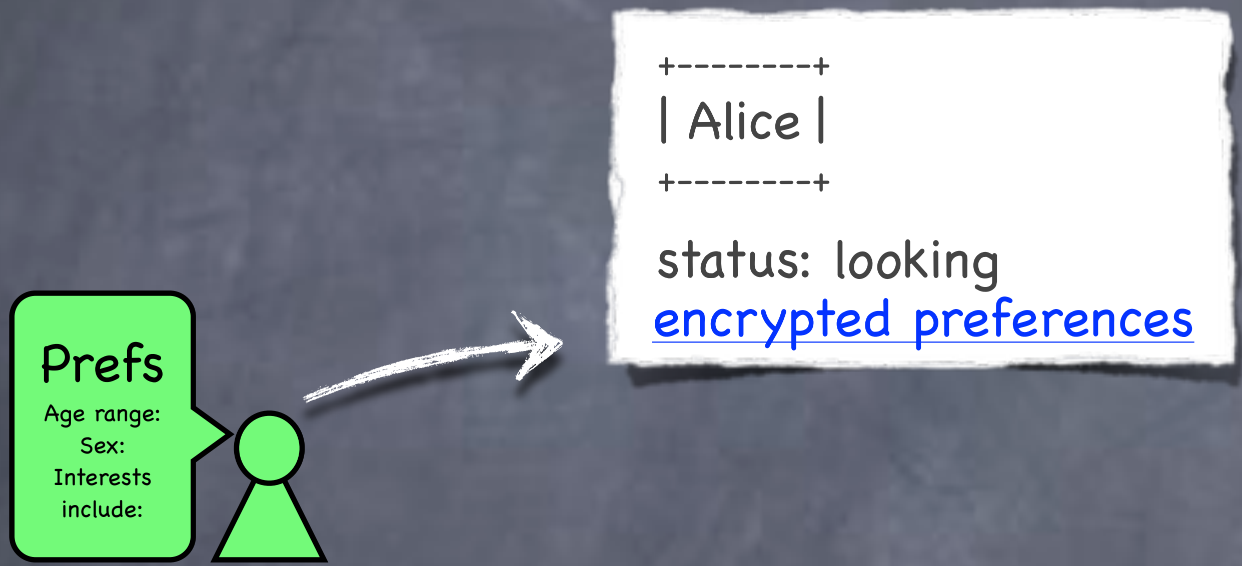

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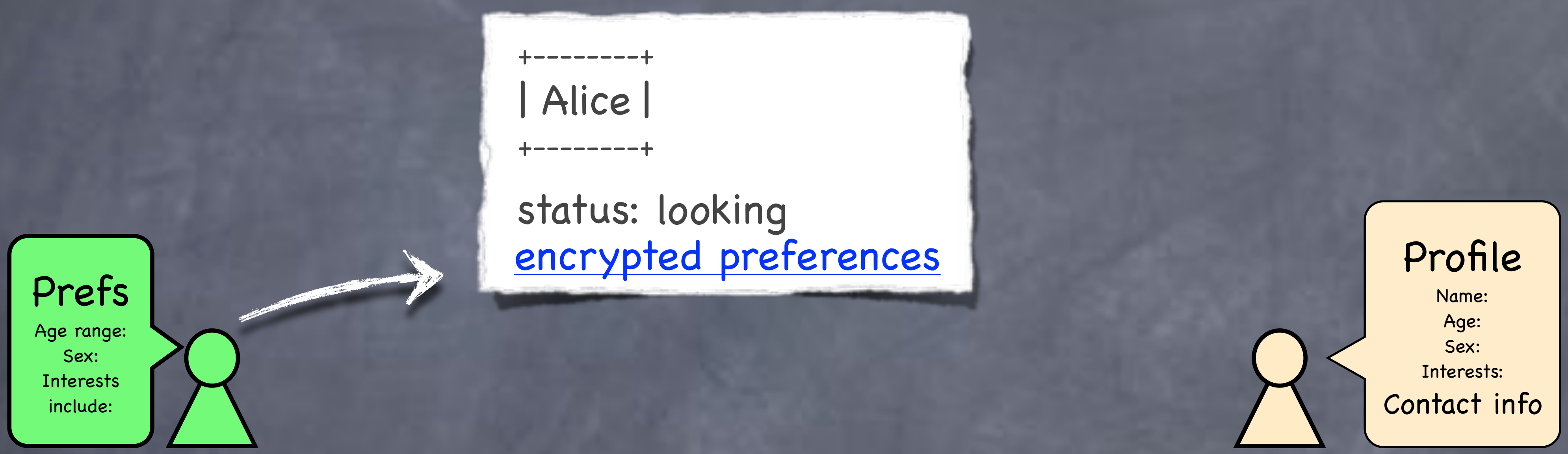

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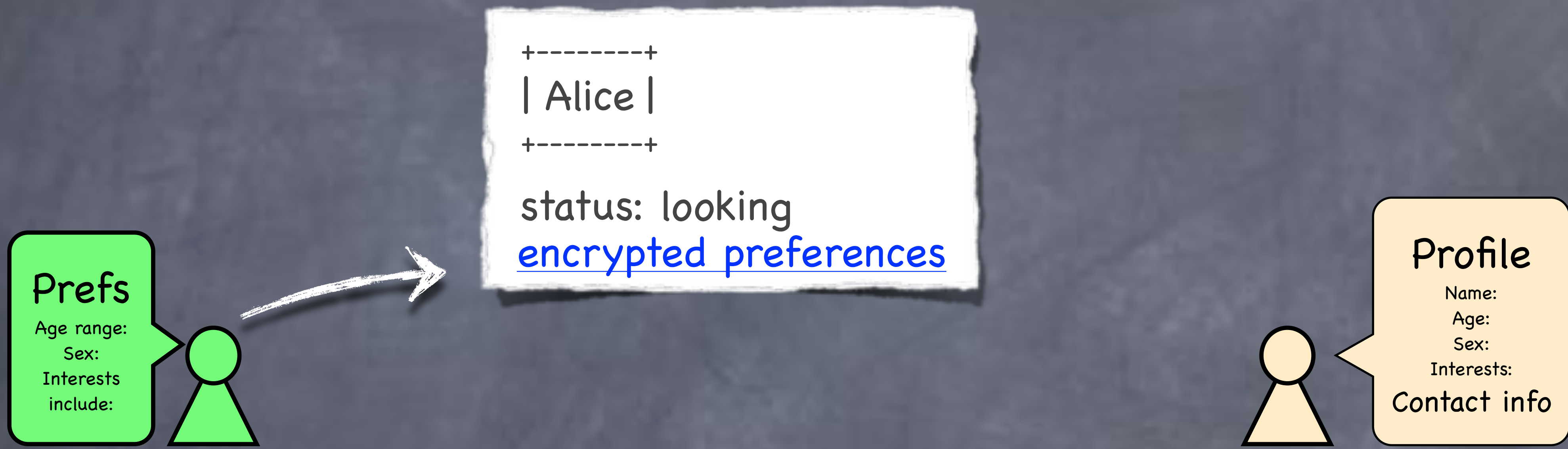

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  Output: If match, then give Bob's contact information to Alice (Bob learns nothing)

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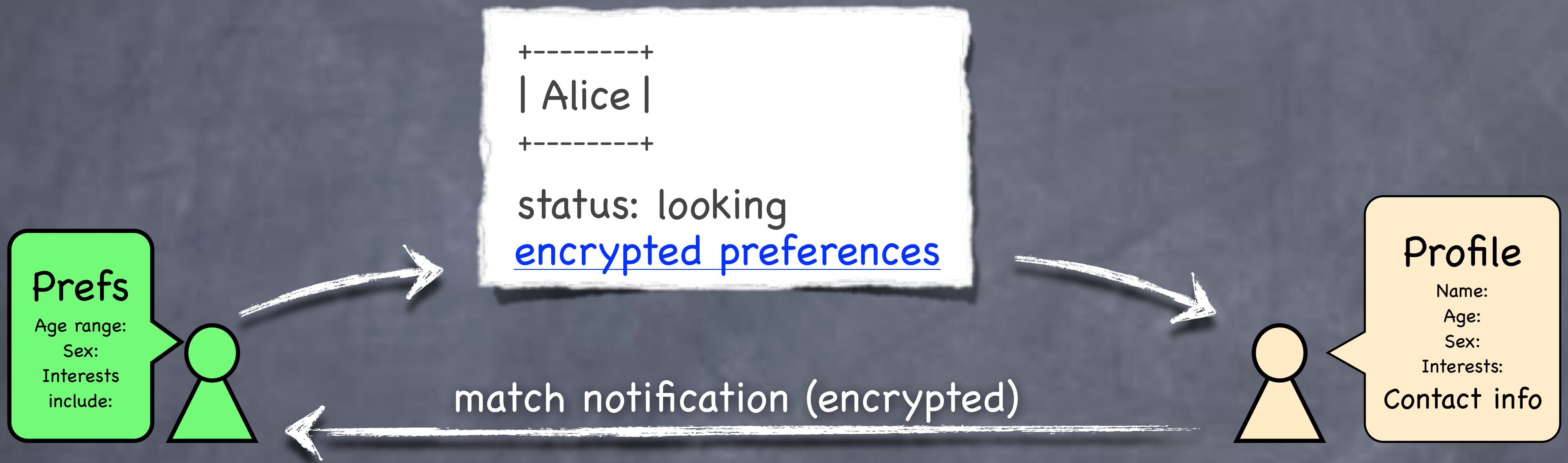

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  Output: If match, then give Bob's contact information to Alice (Bob learns nothing)
- Feature: Alice can post her preferences and go offline

Yao's Garbled Circuit

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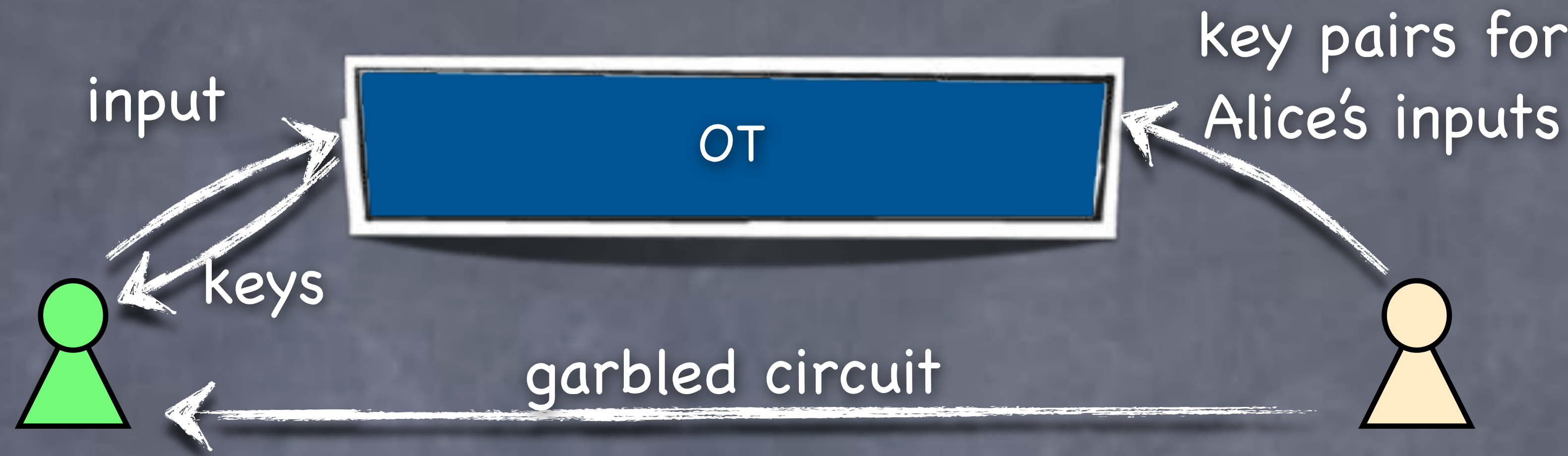
- Allows Alice to compute f(x,y) without learning anything more about y (and without Bob learning about x) [Y'86]



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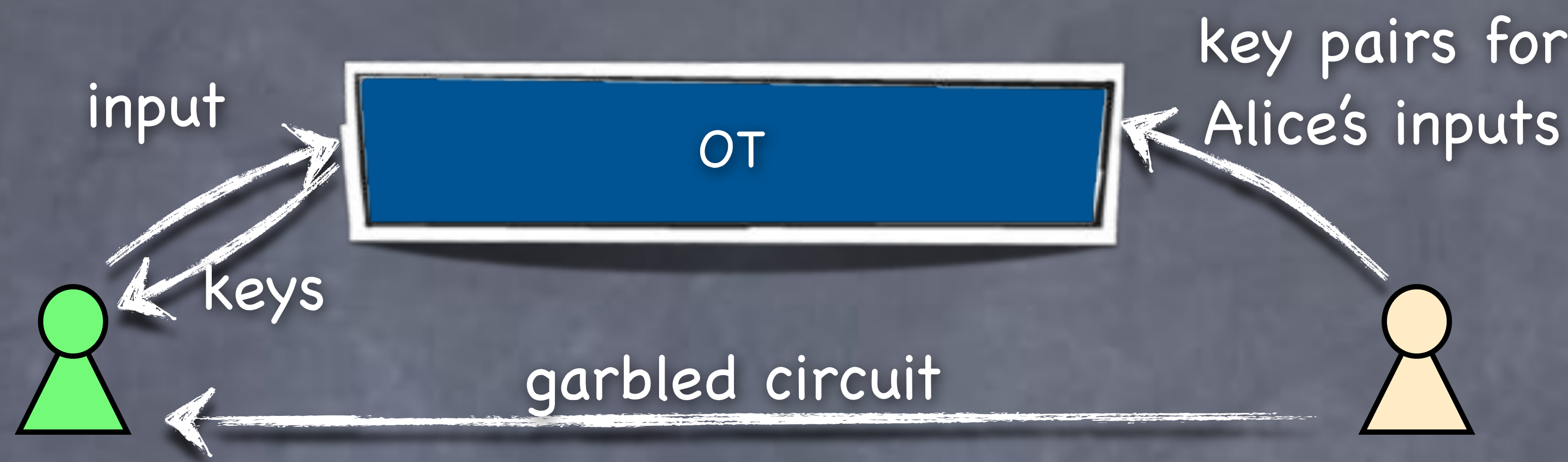

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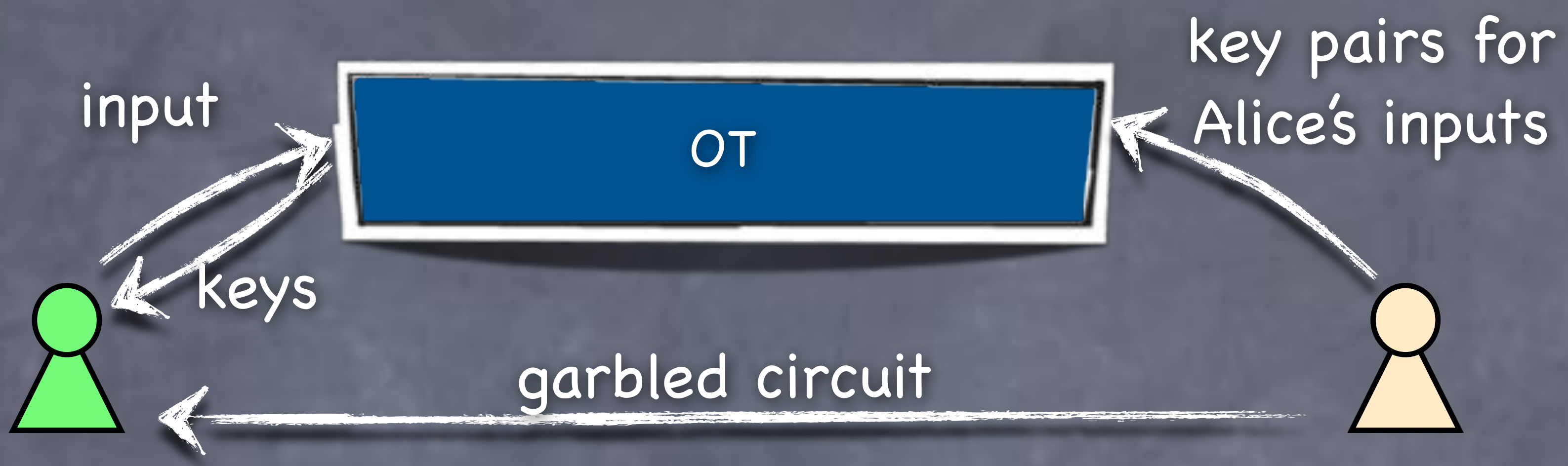

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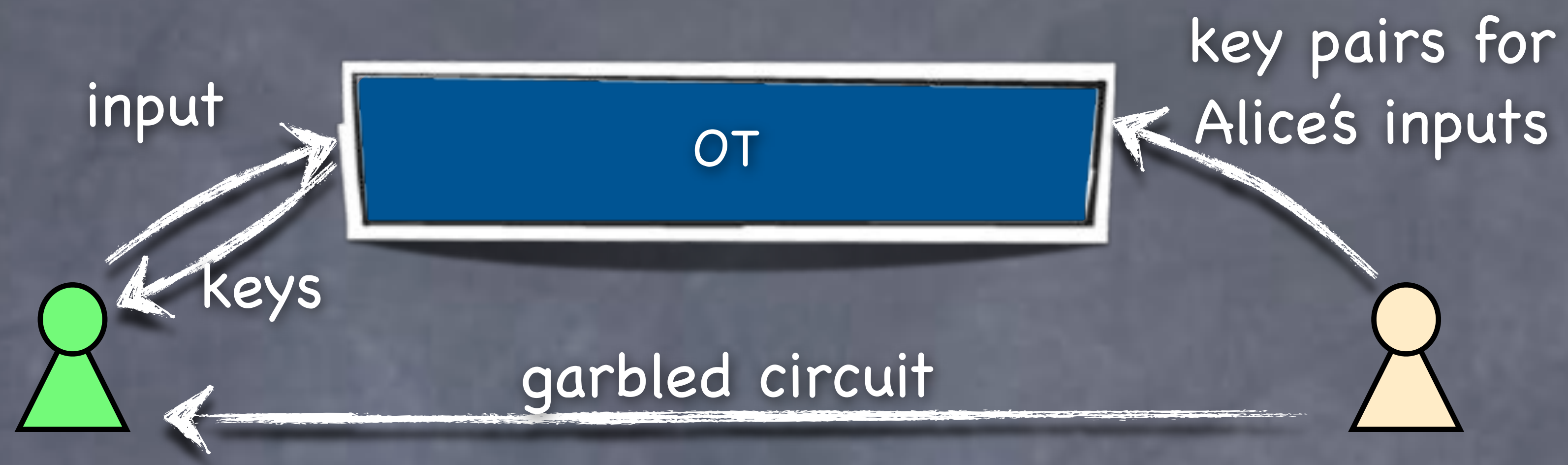

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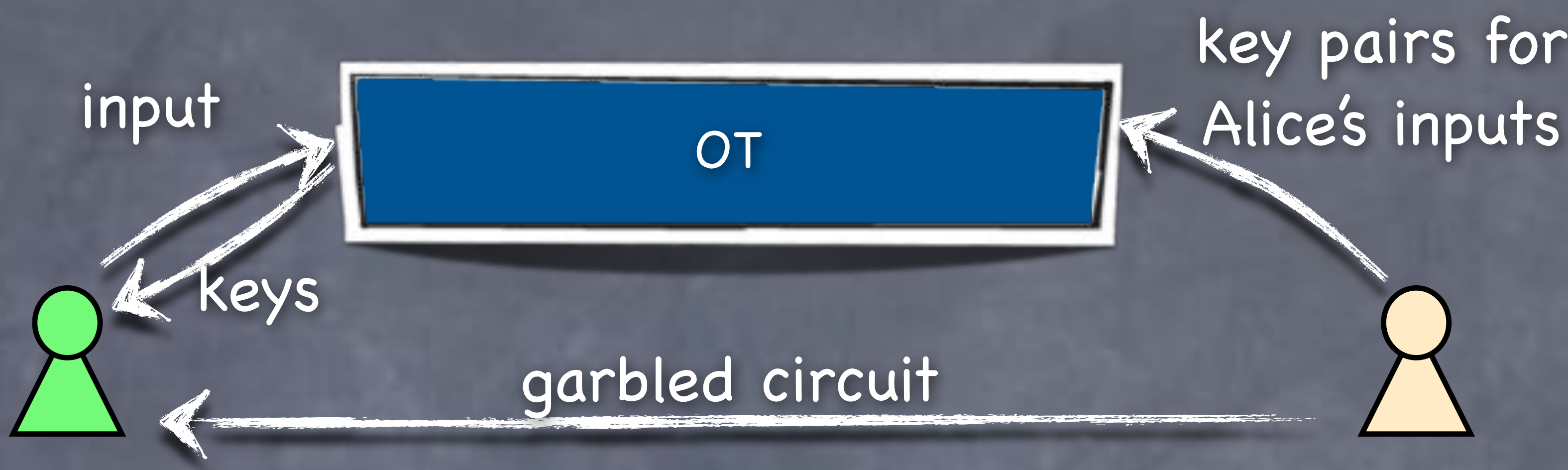

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NIZK
no good!

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- NISC/OT can be converted to NISC/CRS using [PVW'08]

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  - NISC from fully homomorphic encryption [RAD'78,G'09,GHV'10,...]: Low communication (but currently less practical); uses more than PRG+OT
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  - Today: NISC/OT using PRG as a black-box
    - Wide Open: Statistically secure NISC/OT (even constant round MPC) possible for general functions?
      - Open for honest-majority and honest-but-curious settings too

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  - Also, few PRG calls: polylog(κ) per gate of the function's (large) circuit (previously $\Omega(\kappa)$ even for interactive constant-round SFE [LP'07])
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- Also, Reusable NISC in CRS model (using PRG + OT protocol): One reusable "public-key" that Alice publishes and uses in many executions.
  - Issue: public-key must be refreshed each time Alice interacts with the environment (possibly after receiving messages from many Bobs)
  - We show how to allow t such interactions before refreshing, with public-key much shorter than t times the original

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- Maybe good enough in practice: leaks at most one bit (or less, if Alice aggregates many executions before taking any action) of information about Alice's input

Roadmap for NISC/OT

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NISC for NC^0 with IVD-abort

- Step 1: NISC/OT for NC^0 functions (with IVD-abort)

Roadmap for NISC/OT

Using Yao's garbled circuit and Oblivious MAC

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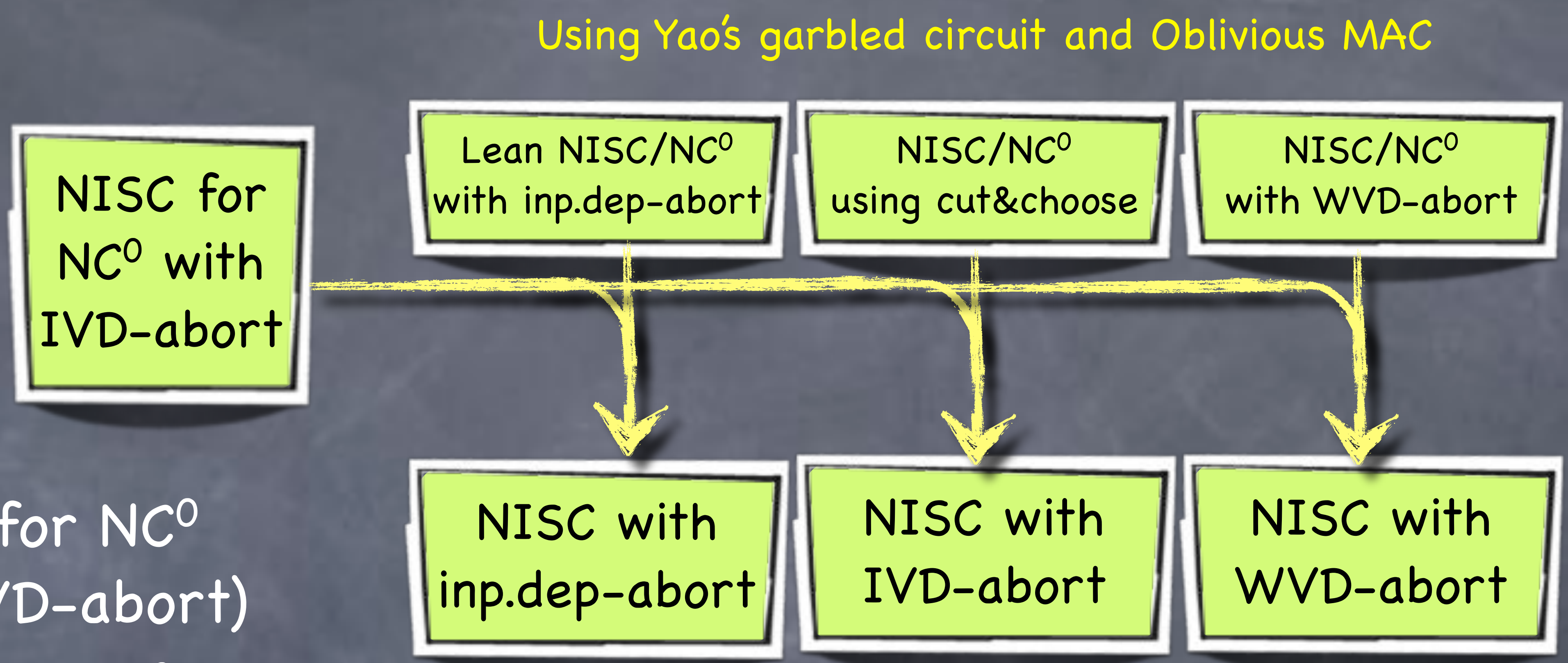

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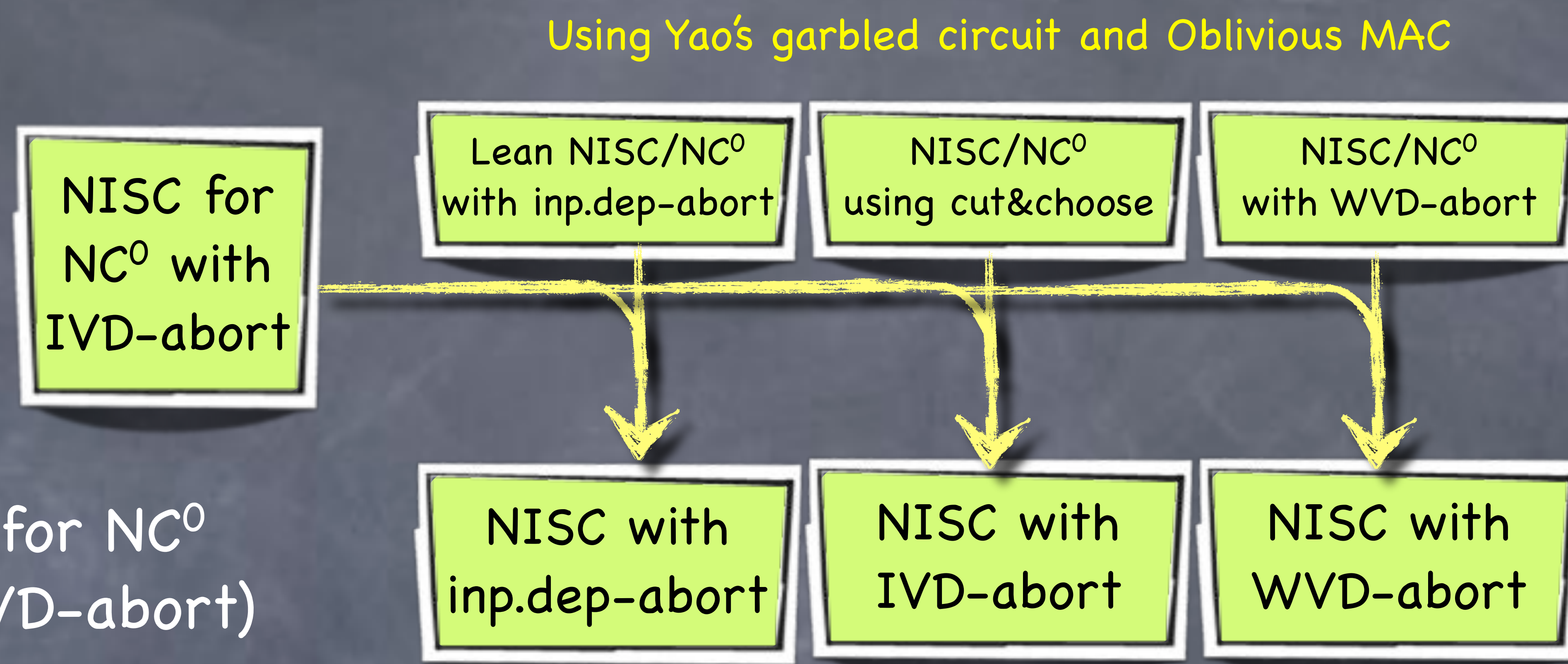

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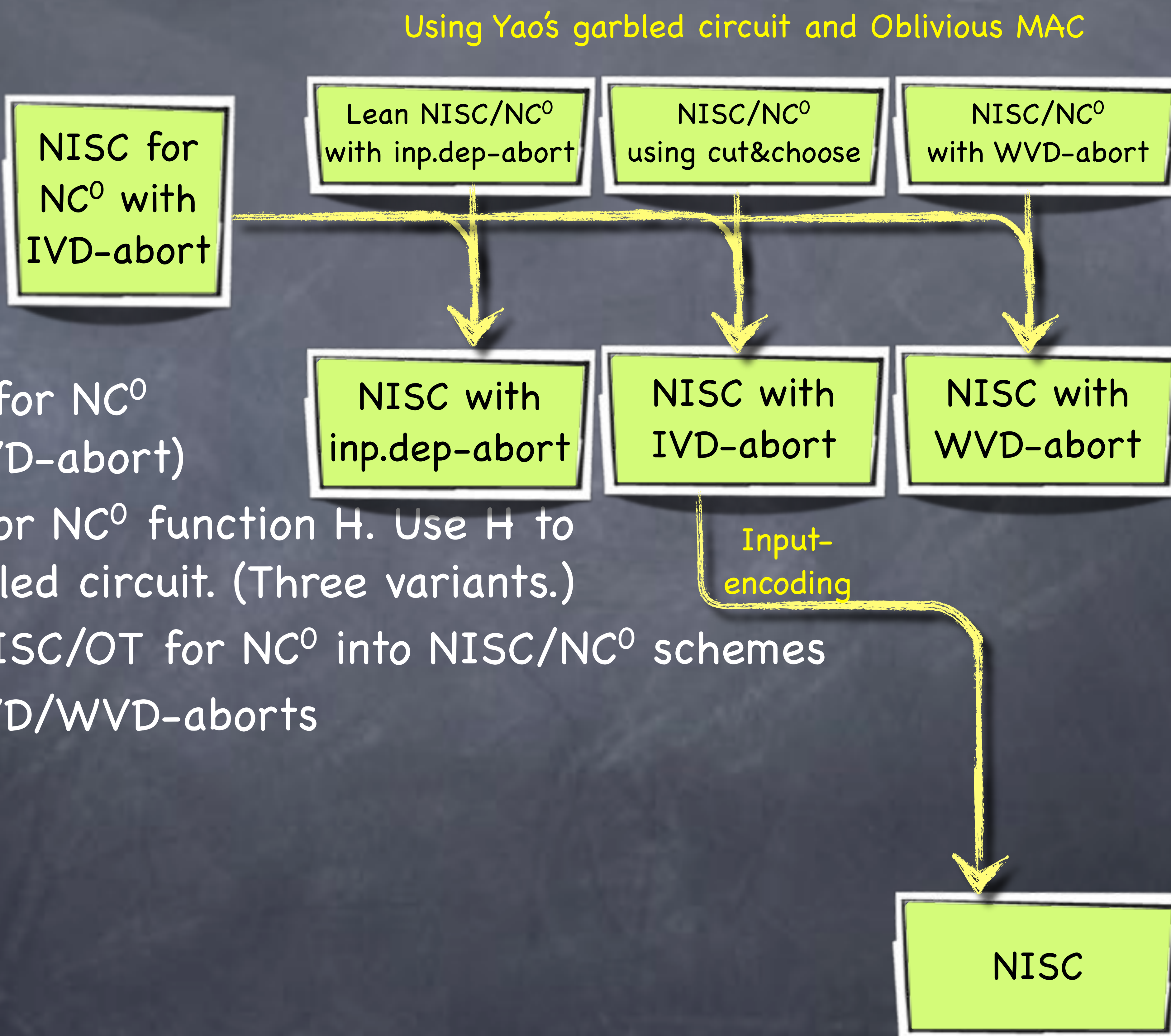

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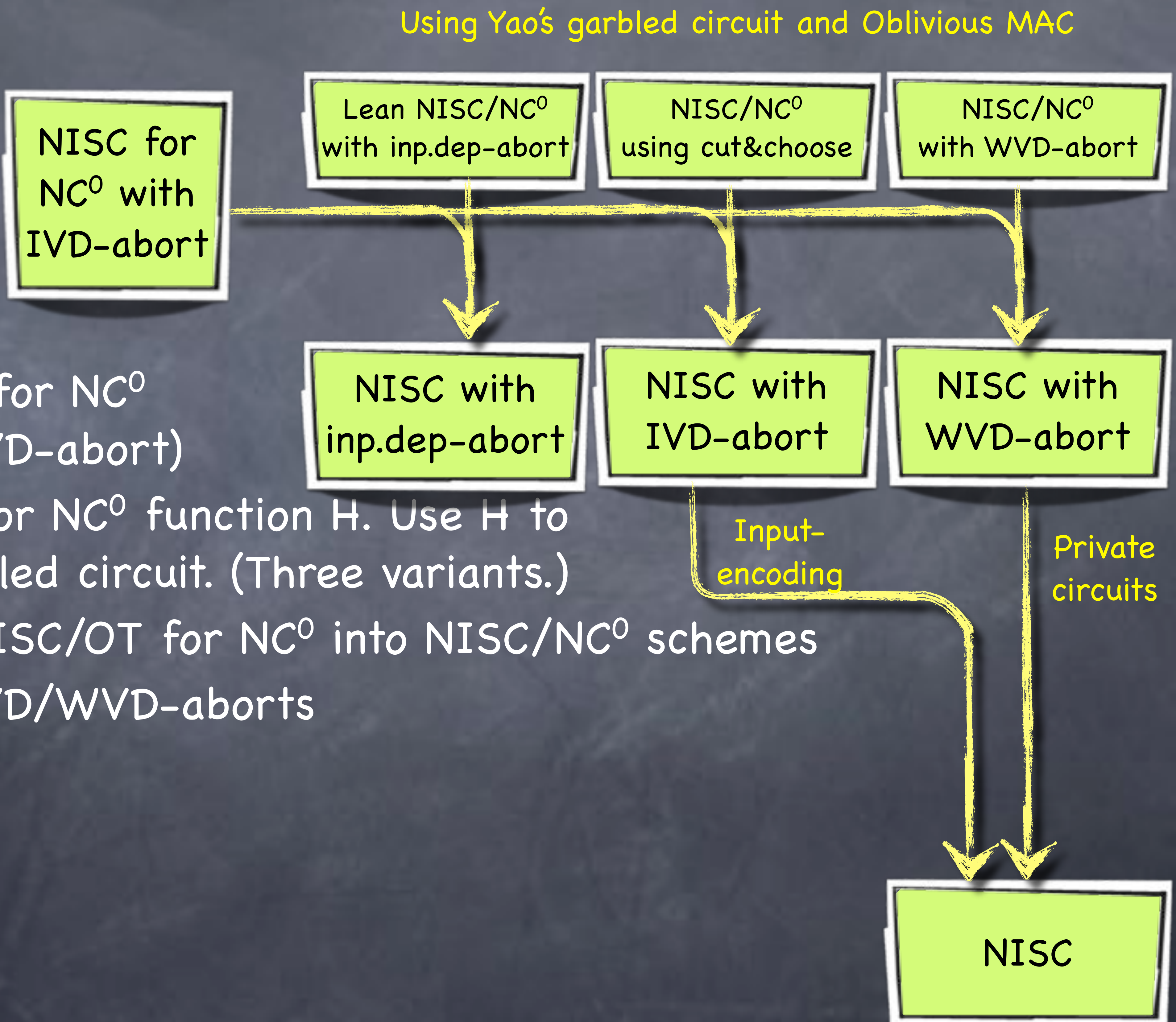

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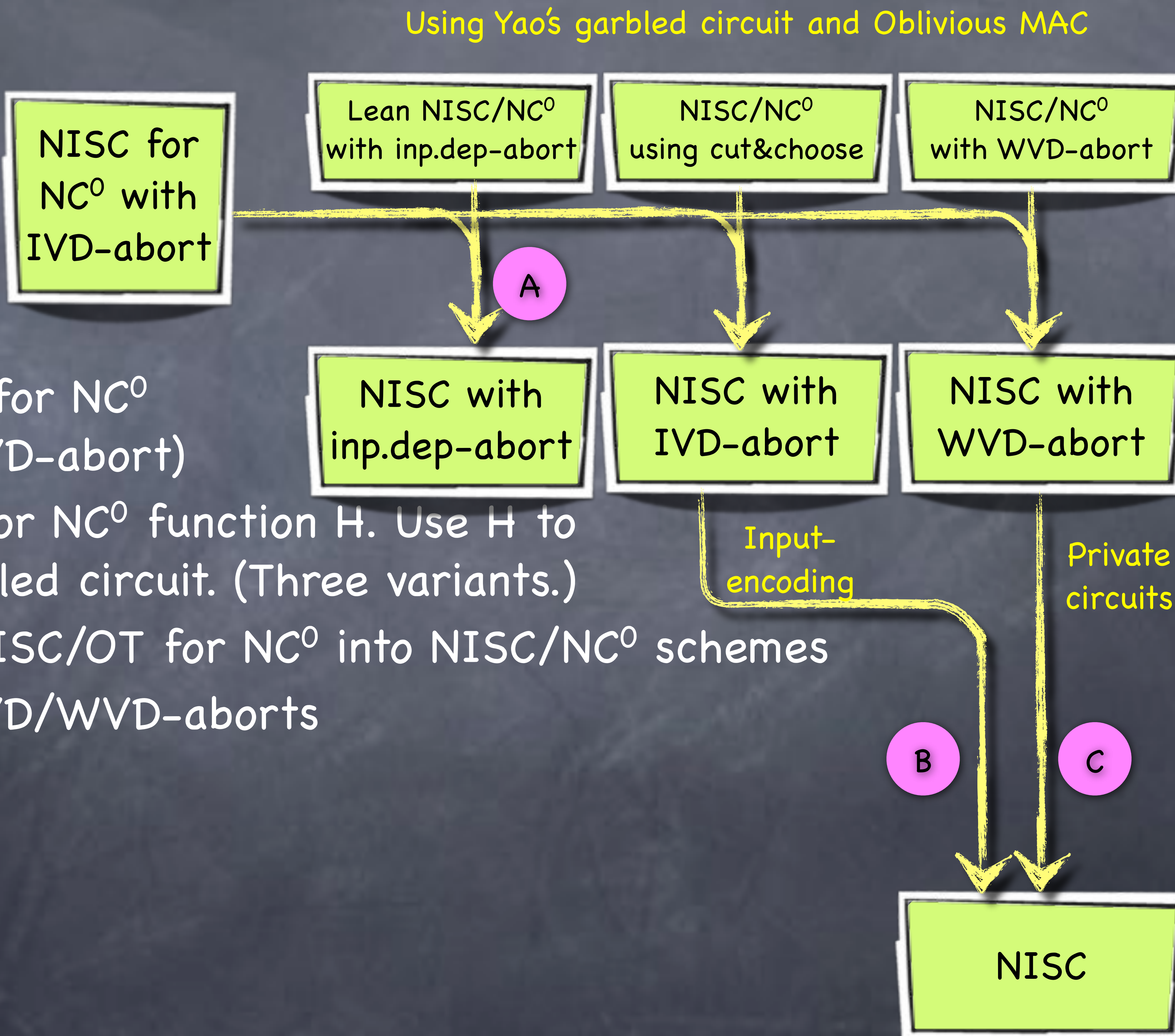

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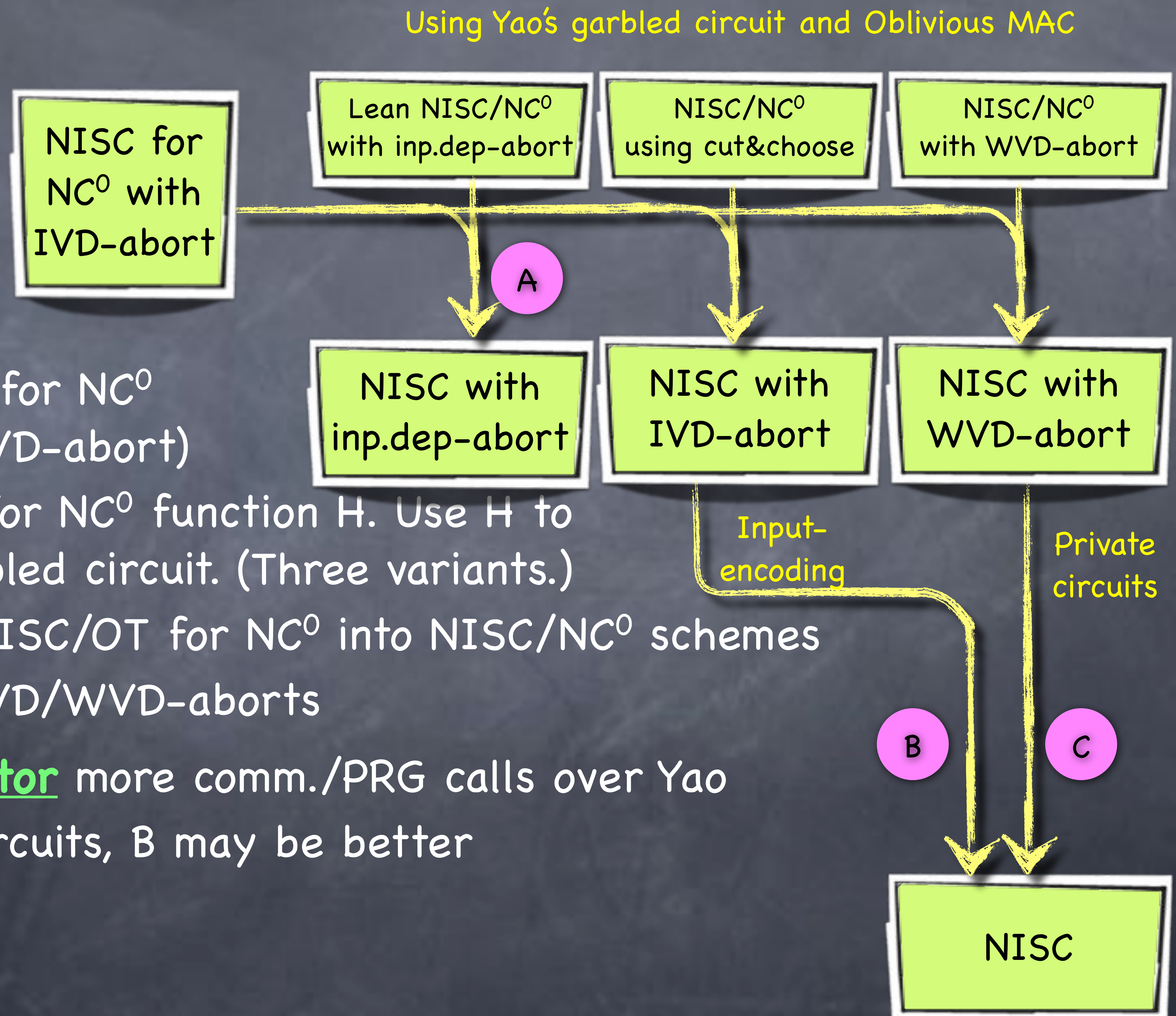

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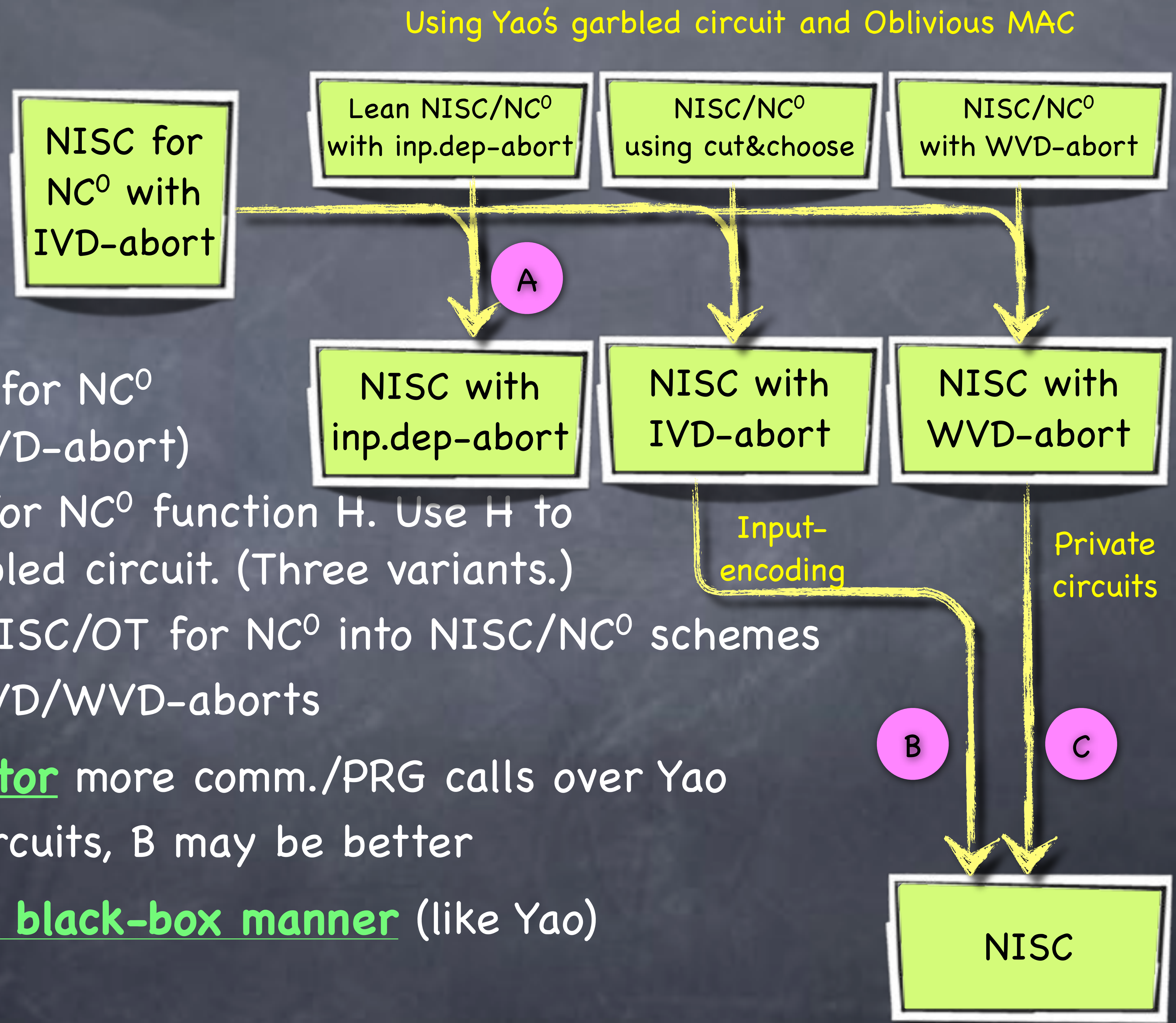

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- **All use PRG in a black-box manner** (like Yao)

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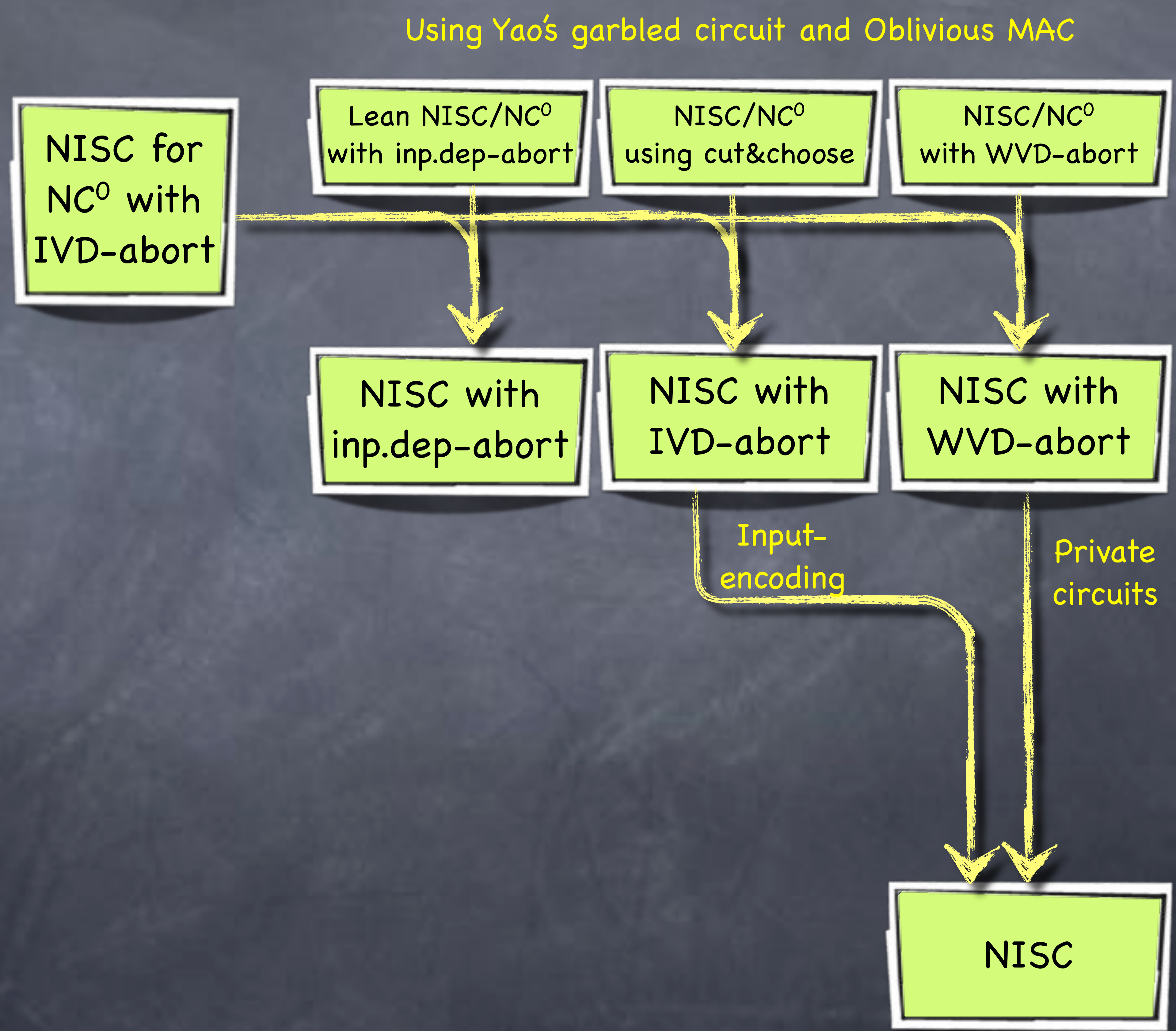

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Input-encoding
Private circuits
NISC

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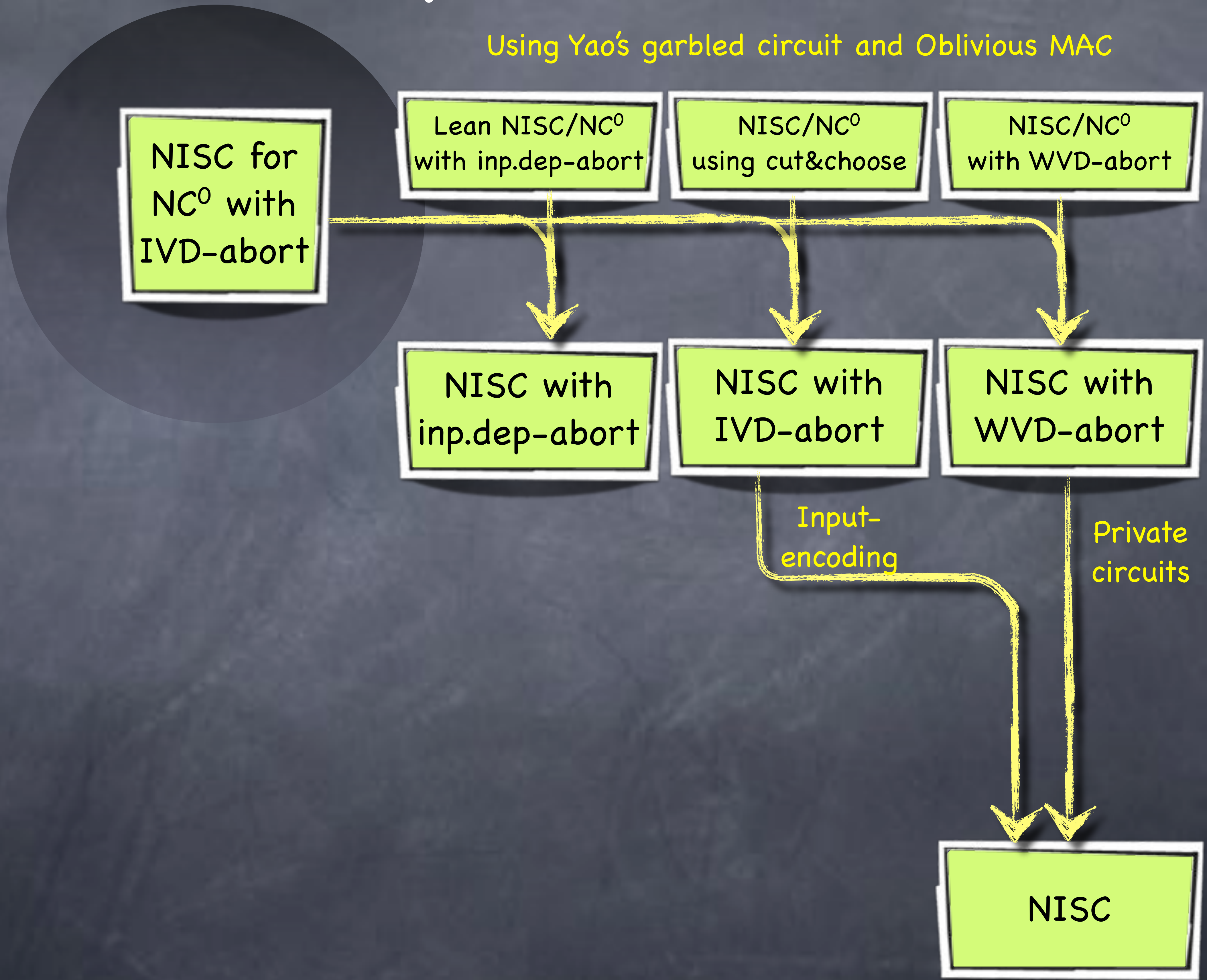

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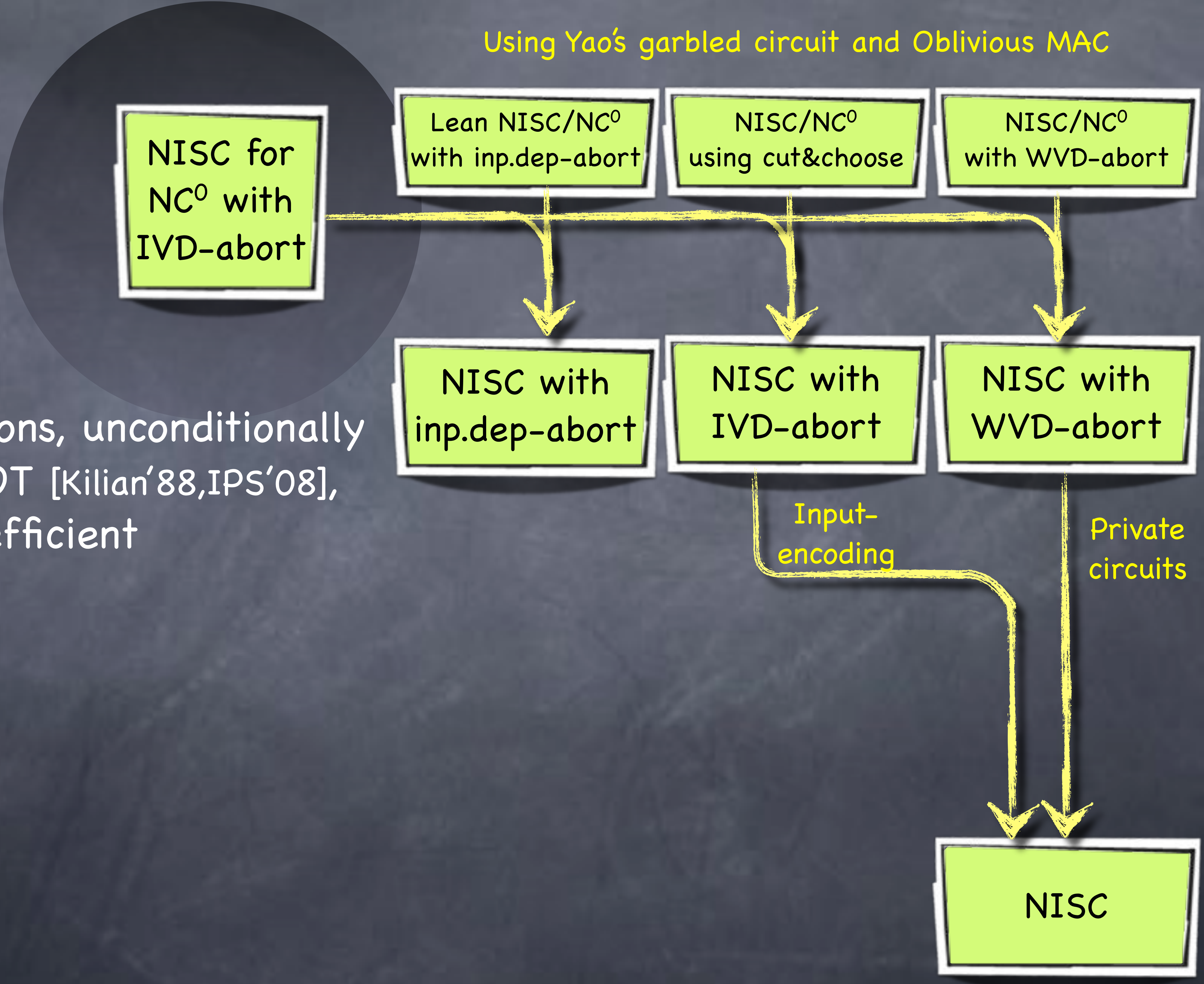

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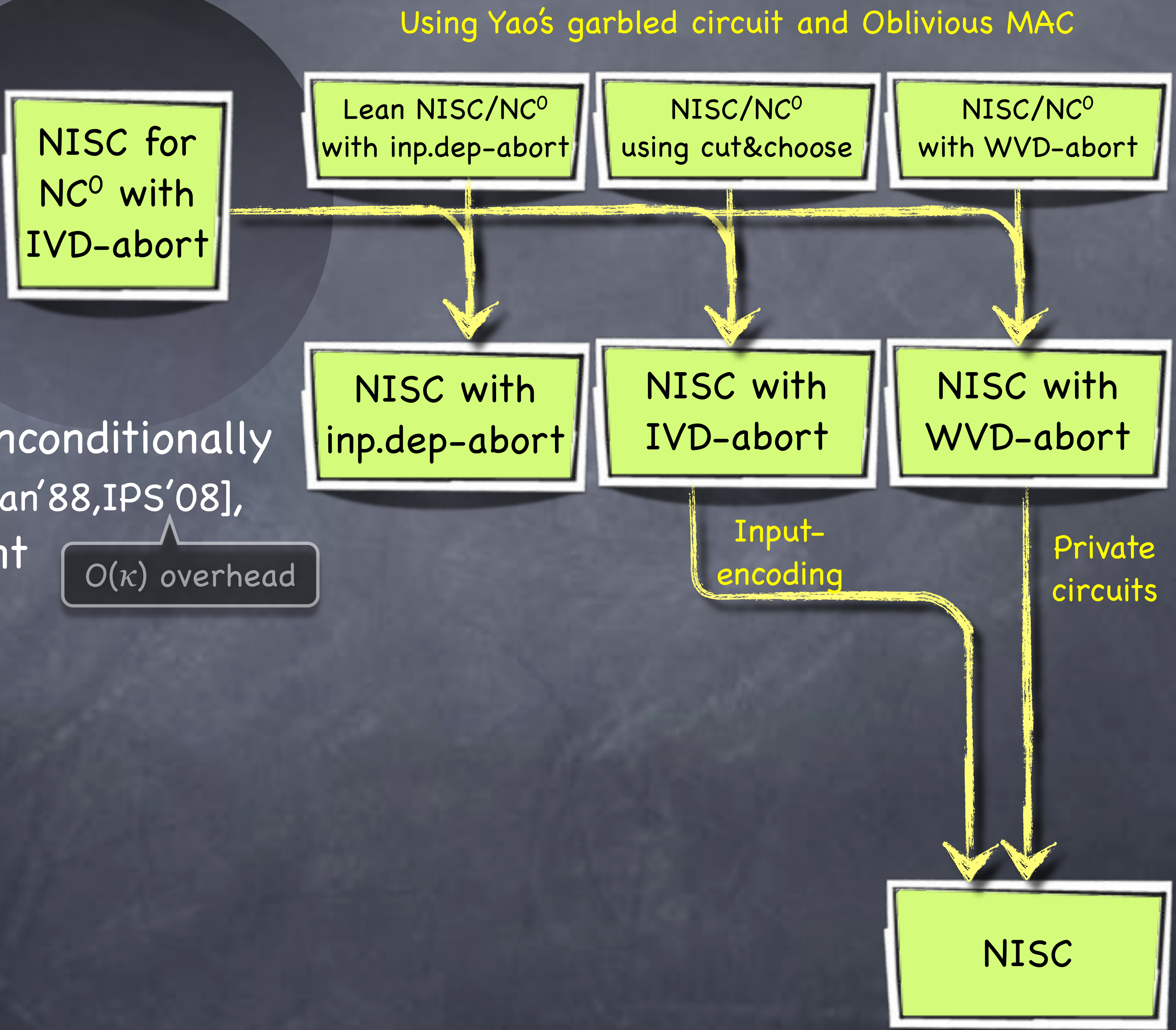

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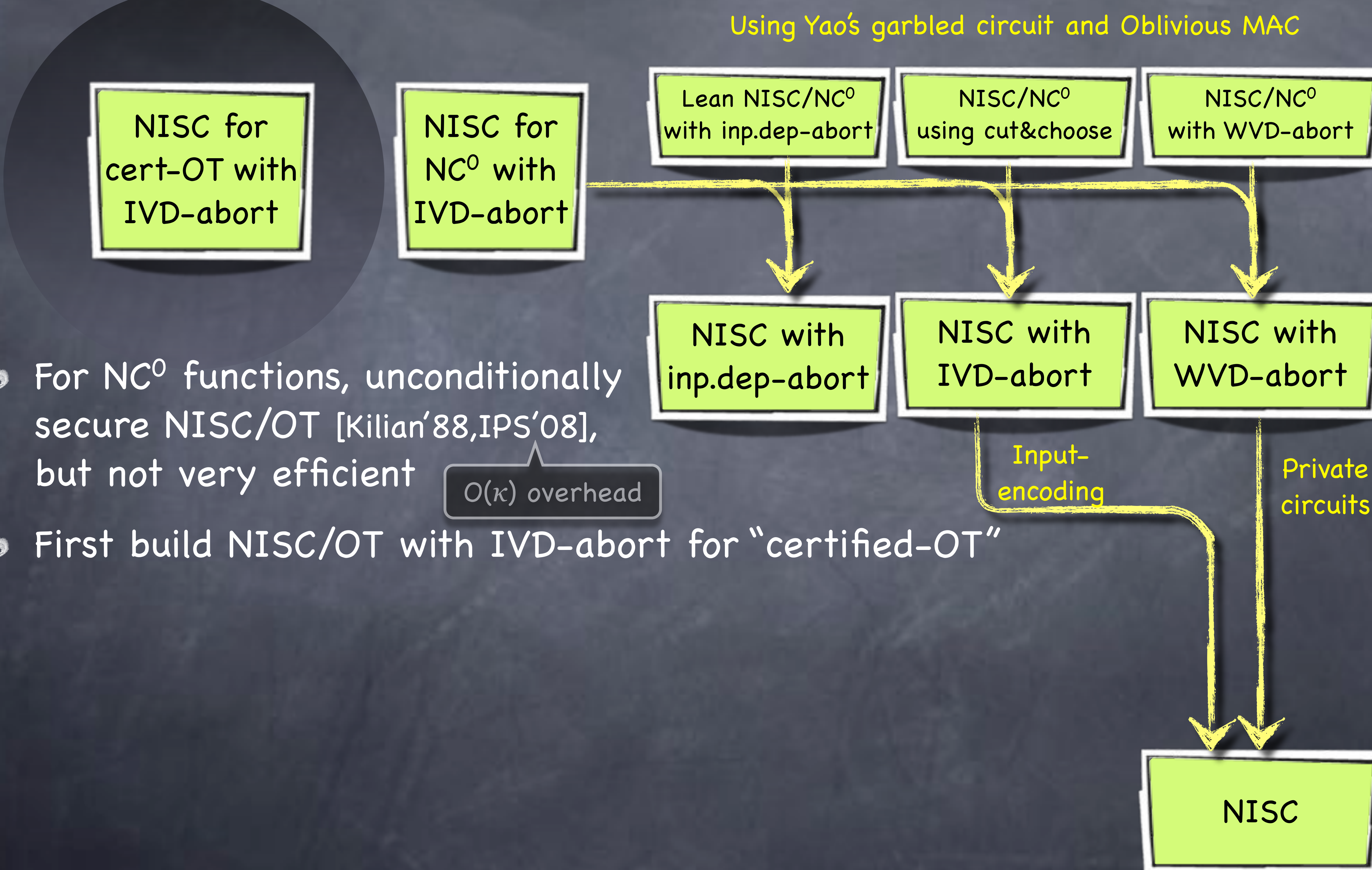

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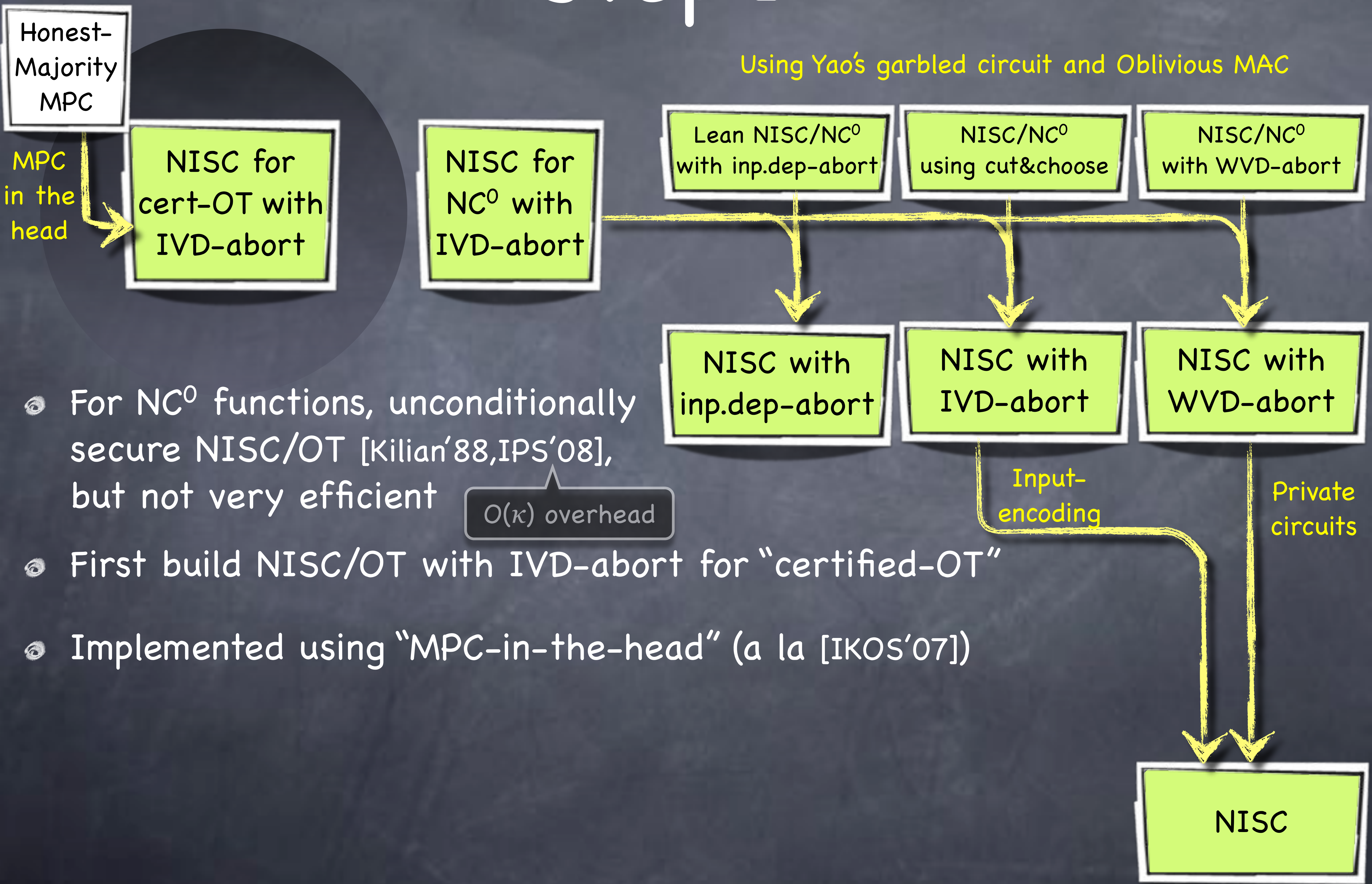

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Honest-Majority MPC

MPC in the head

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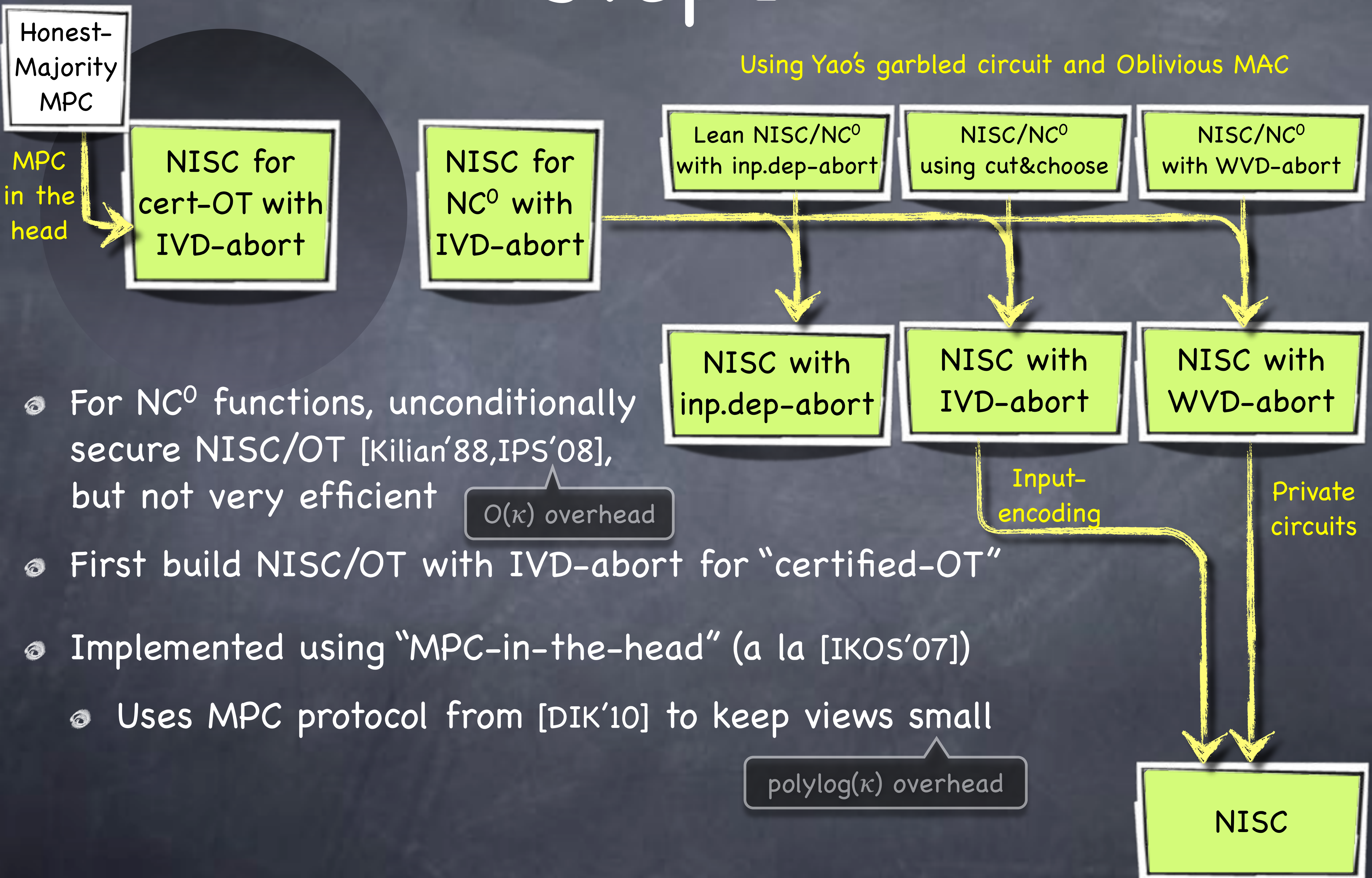

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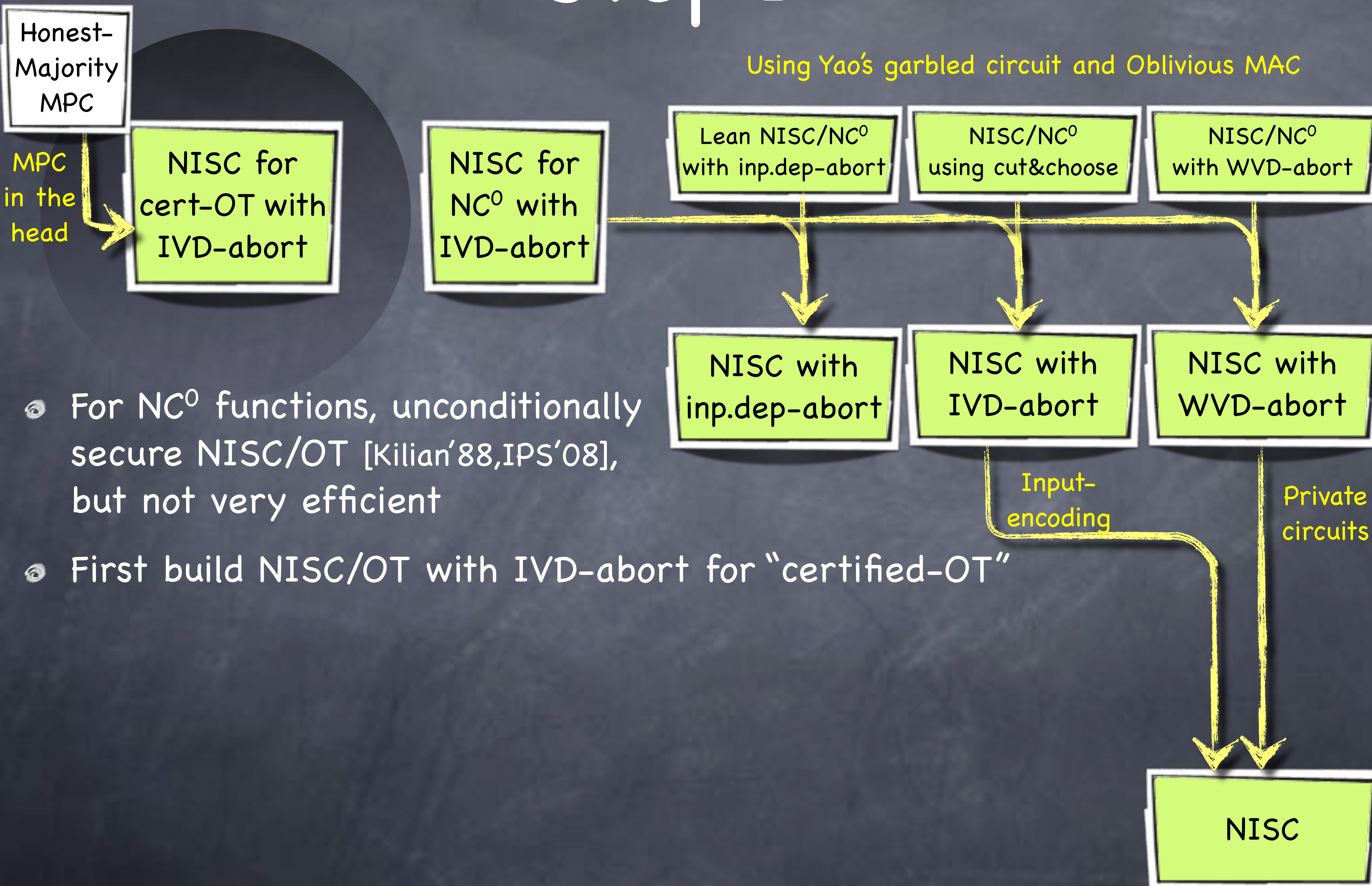

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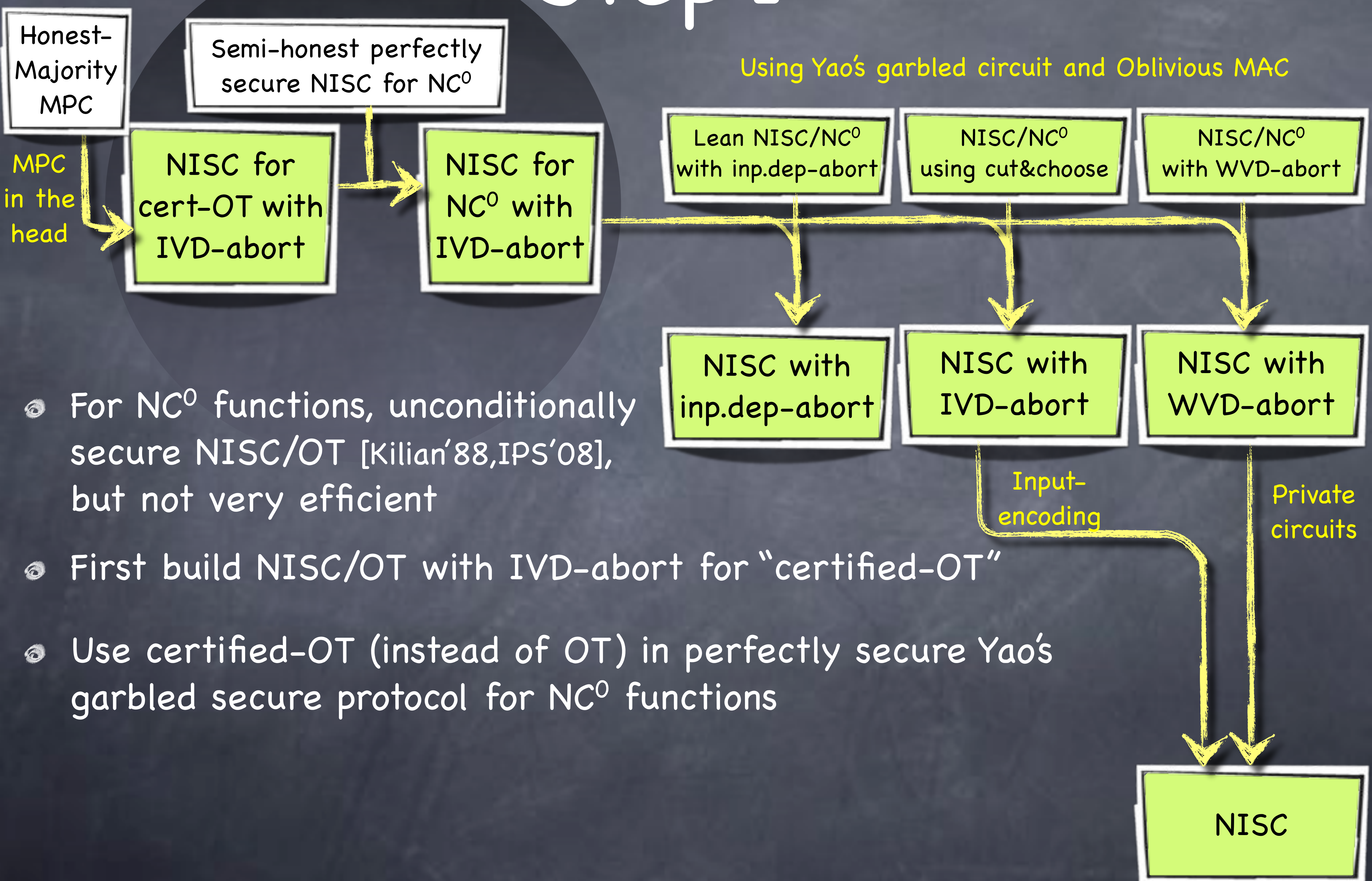

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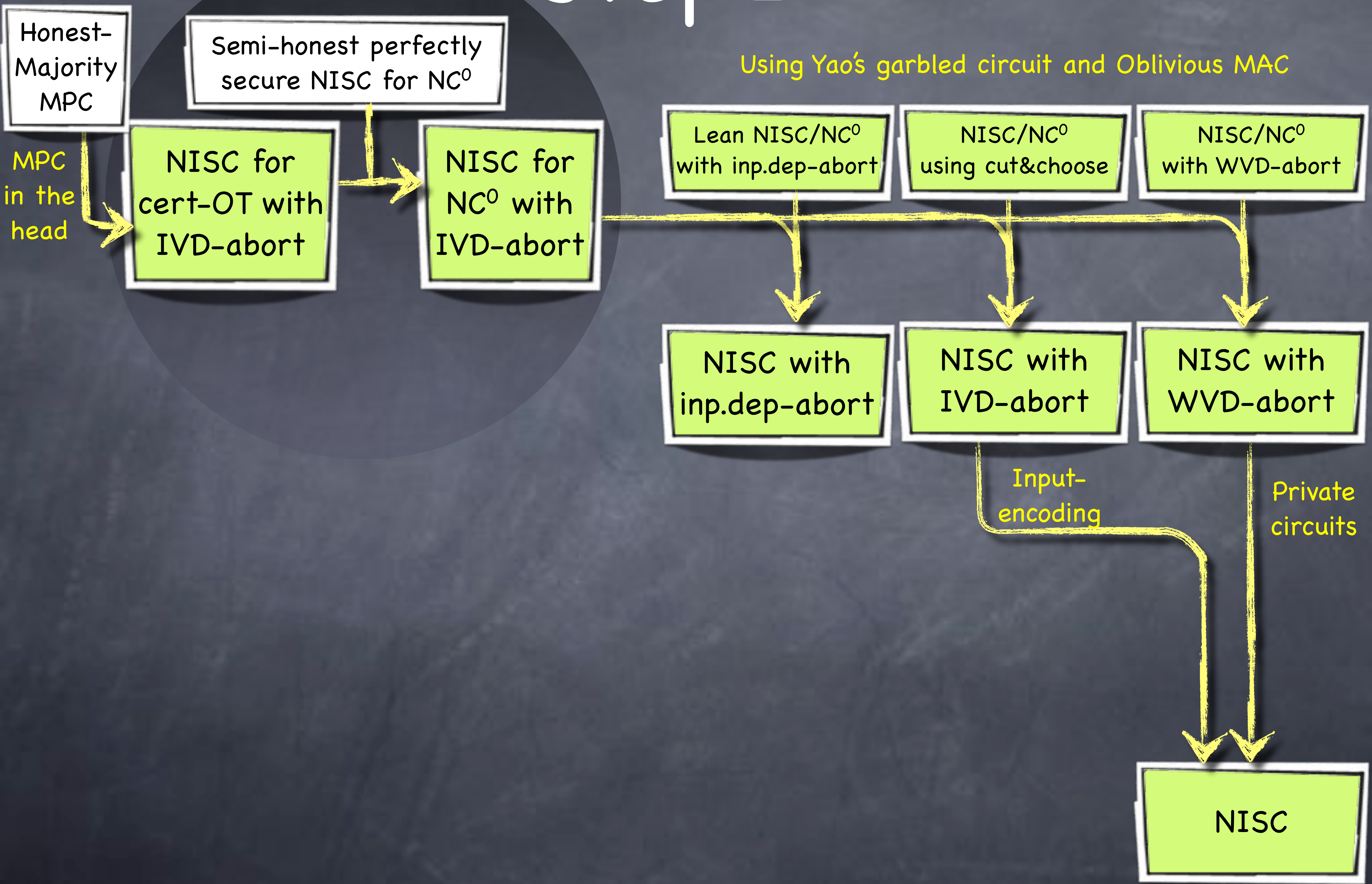
- First build NISC/OT with IVD-abort for "certified-OT"
- Use certified-OT (instead of OT) in perfectly secure Yao's garbled secure protocol for NC^0 functions

Step 2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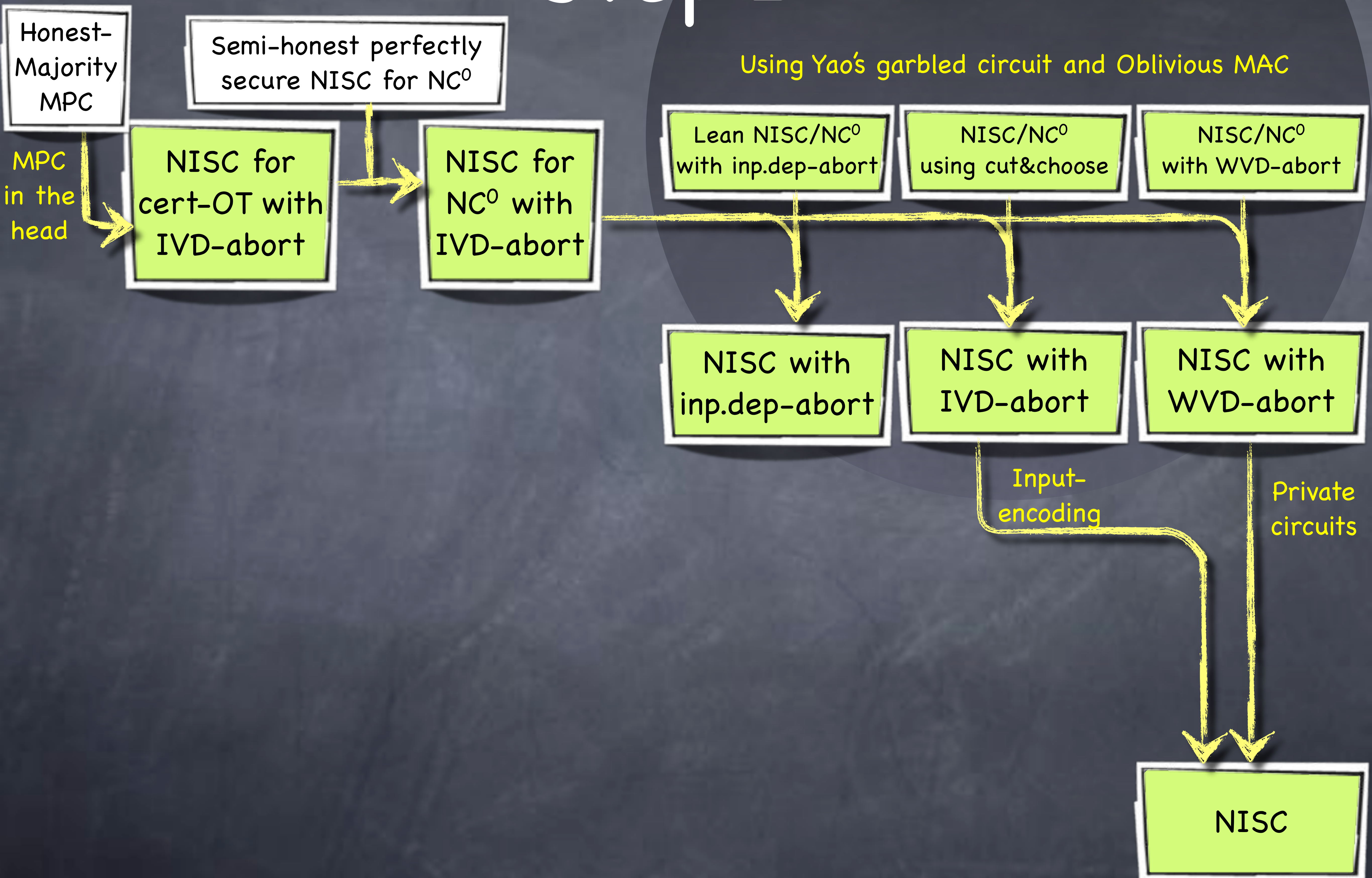

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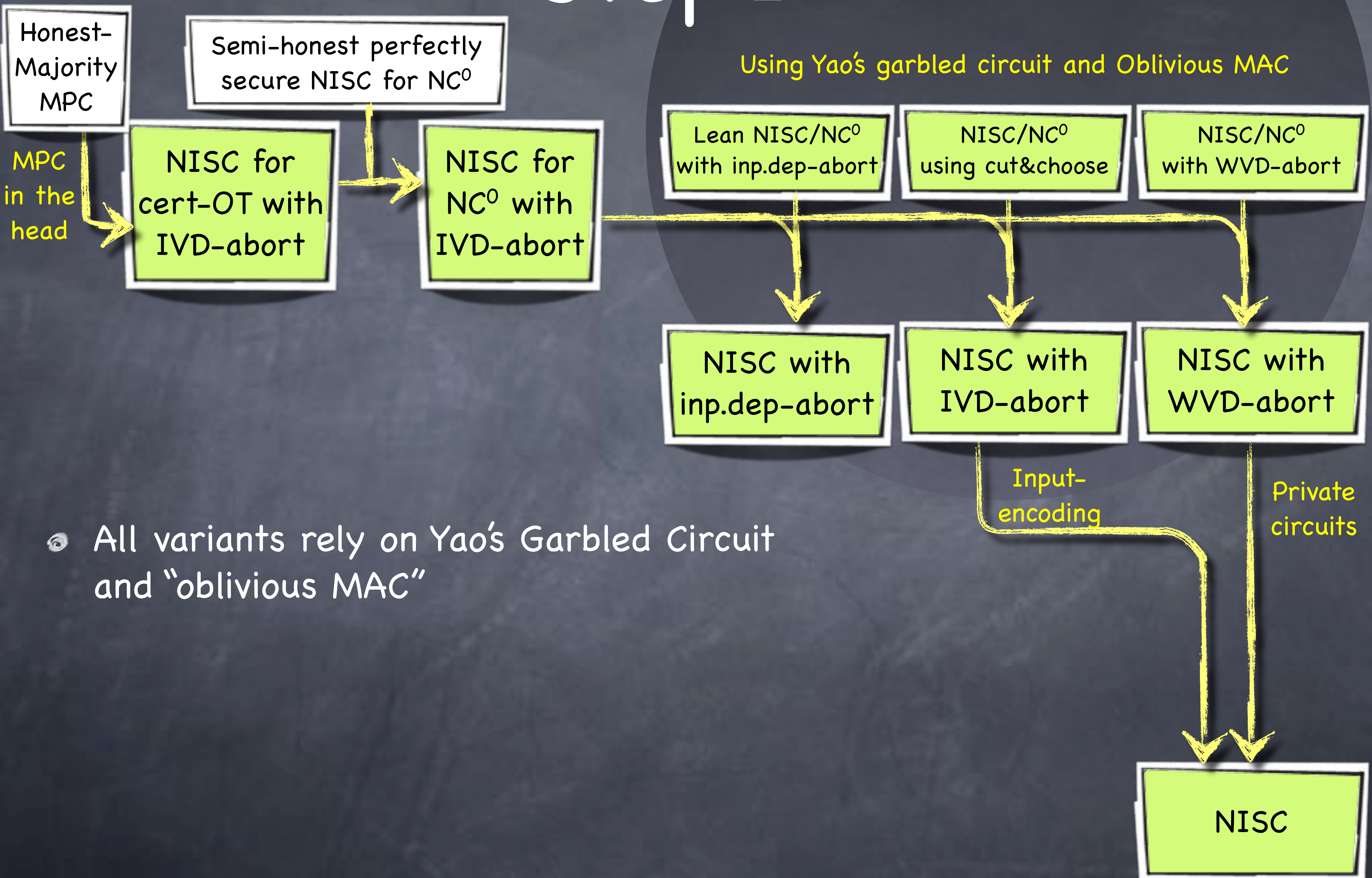

- All variants rely on Yao's Garbled Circuit and "oblivious MAC"

Yao’s Garbled Circuit

Yao's Garbled Circuit

- Bob sends a garbled circuit to Alice

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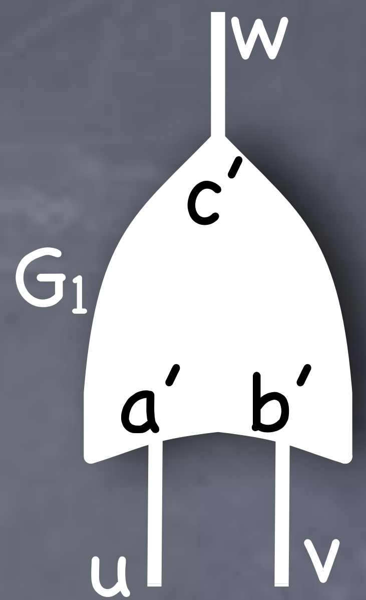

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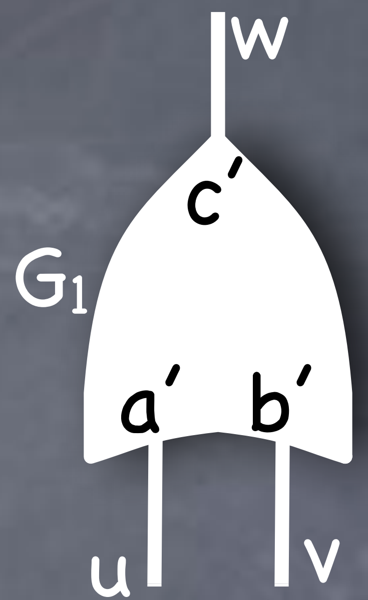

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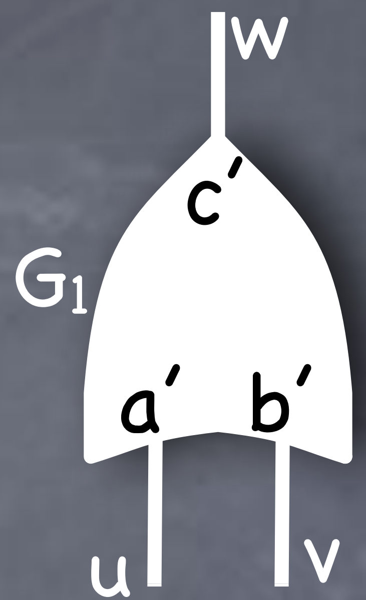

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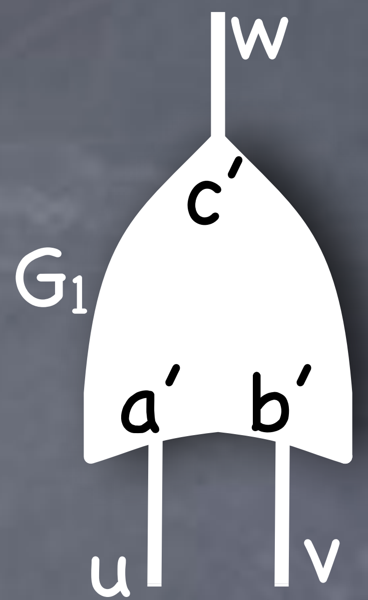
Gate	a'	b'	$c'=F_G(a,b)'$
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	0

Yao's Garbled Circuit



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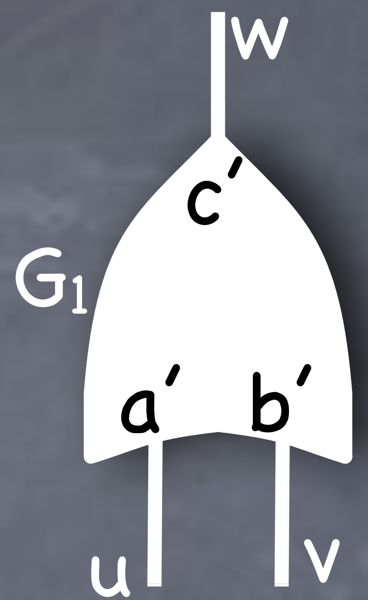
Gate	a′	b′	$c' = F_G(a,b)'$
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	0
		...	
N	0	0	1
N	0	1	0
N	1	0	1
N	1	1	1

Yao's Garbled Circuit



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...			
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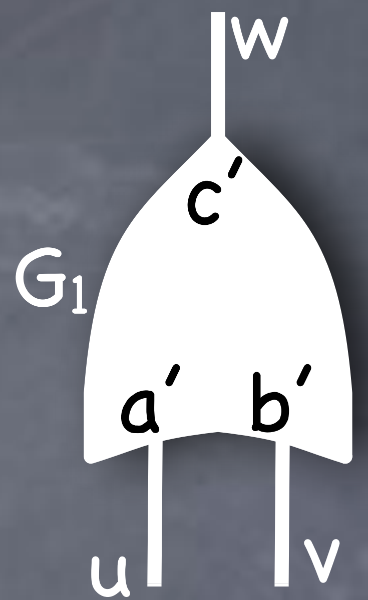

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    - Store $[c',K_w(c')]_{G,a',b'}$: $(c',K_w(c'))$ encrypted using $K_u(a')$ & $K_v(b')$
- Alice can evaluate the circuit if $(z_w',K_w(z_w'))$ known for all input wires w, with value z_w

Gate	a′	b′	c′=F_G(a,b)′
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	0
...			
N	0	0	1
N	0	1	0
N	1	0	1
N	1	1	1

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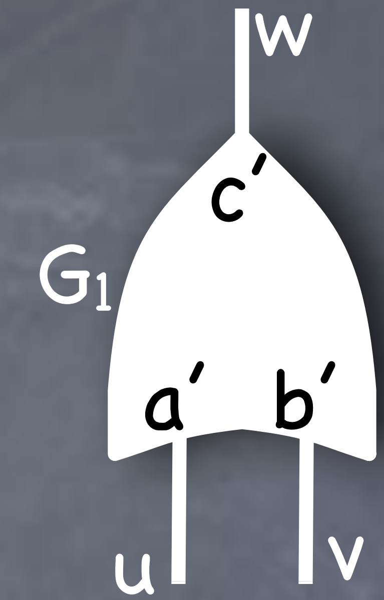

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1	0	1	0
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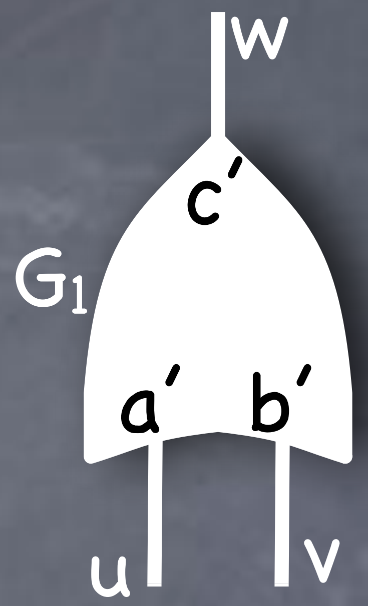
Yao's Garbled Circuit



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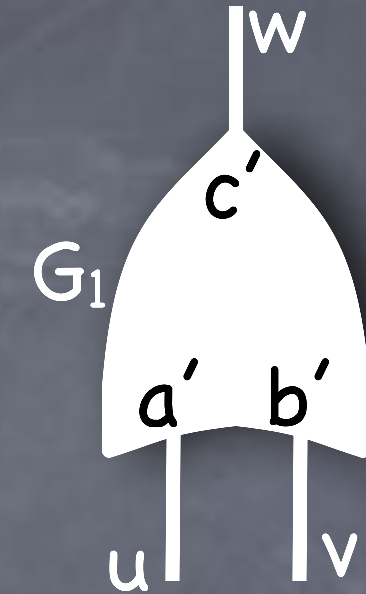

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    Malicious Bob can pick arbitrary c′!

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Oblivious MAC (OM)

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- Obliviousness: If tag chosen at random, then receipt by itself reveals no information about msg
- Correctness: Verify(msg,tag;key,rcpt) = 1
- Unforgeability: can't find (msg,tag) and (msg',tag') s.t. msg' ≠ msg, and for rcpt=$\mathrm{OM}_{\mathrm{key}}$(msg,tag), Verify(msg',tag';key,rcpt) = 1

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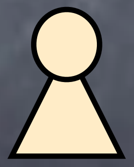
A Lean NISC/NC^0

With Input-Dependent Abort Security



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A Lean NISC/NC^0

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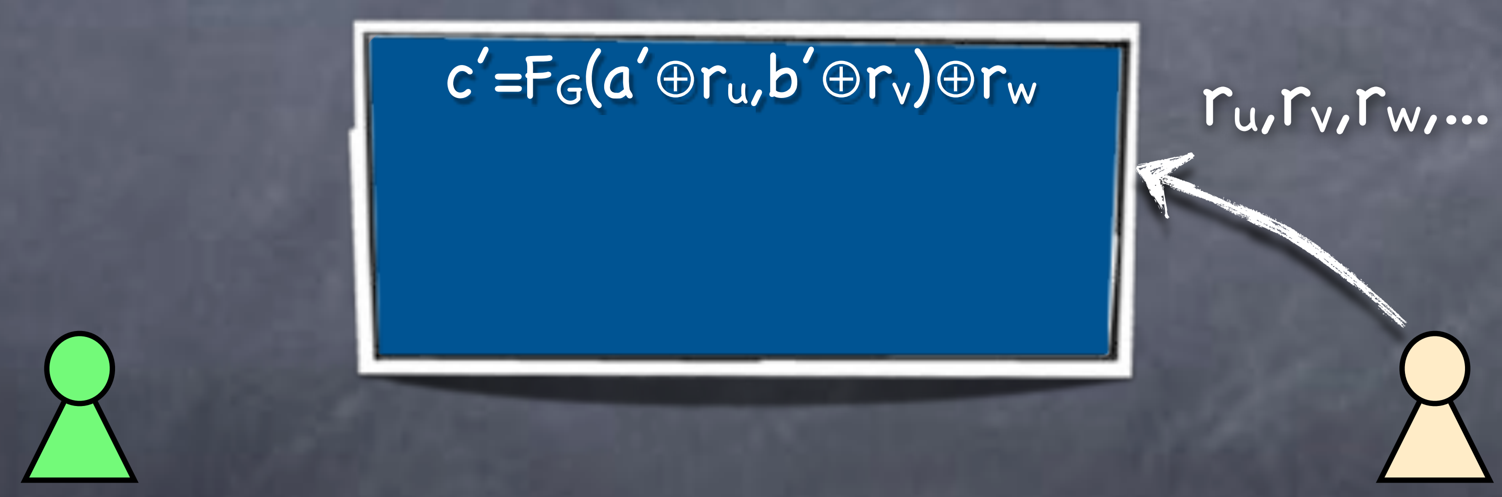

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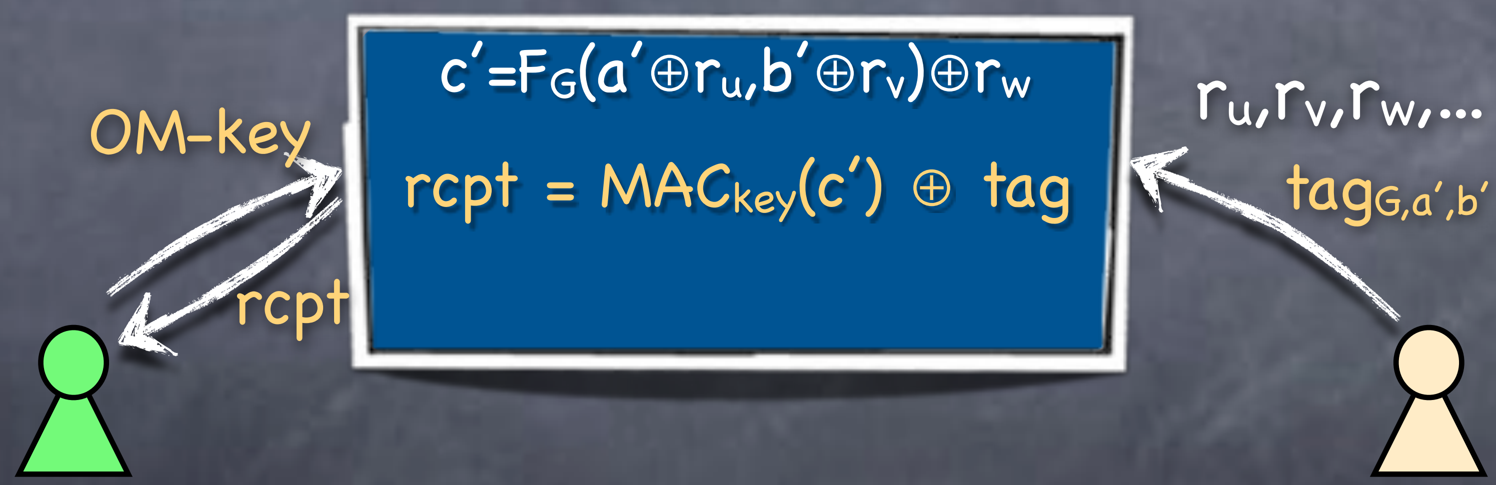

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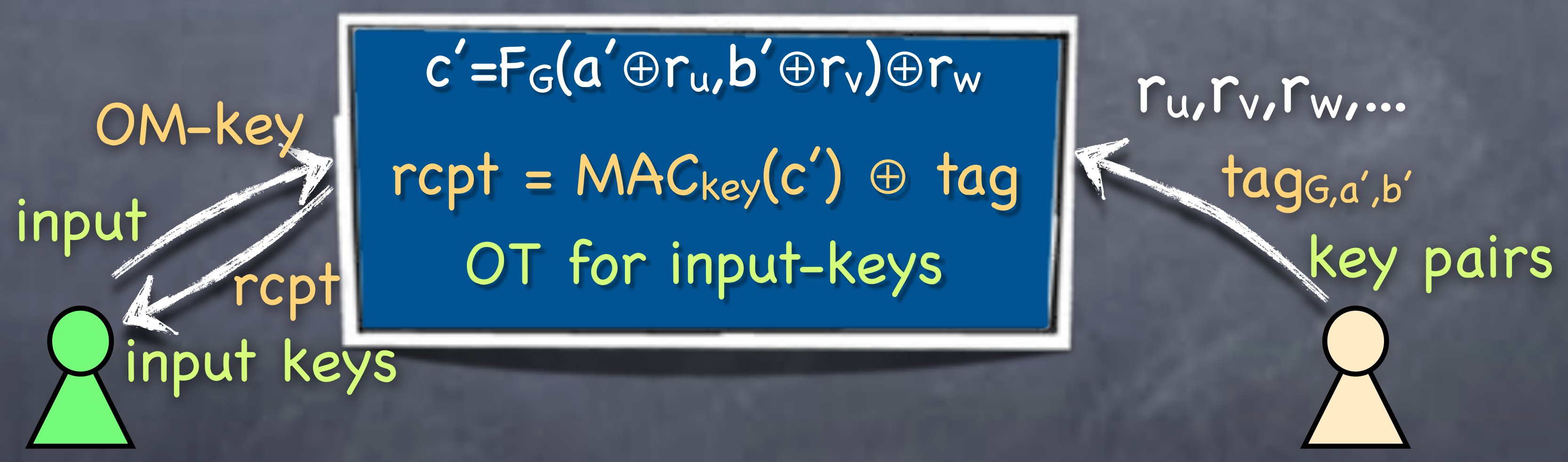

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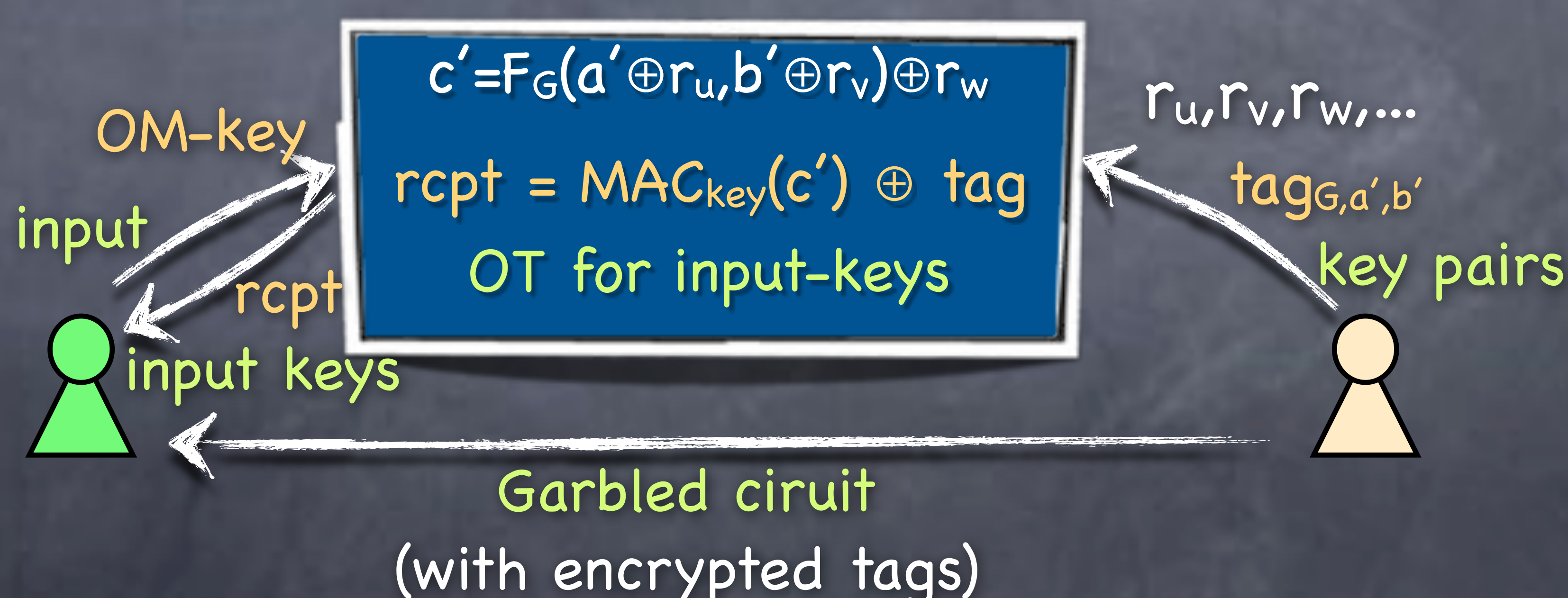

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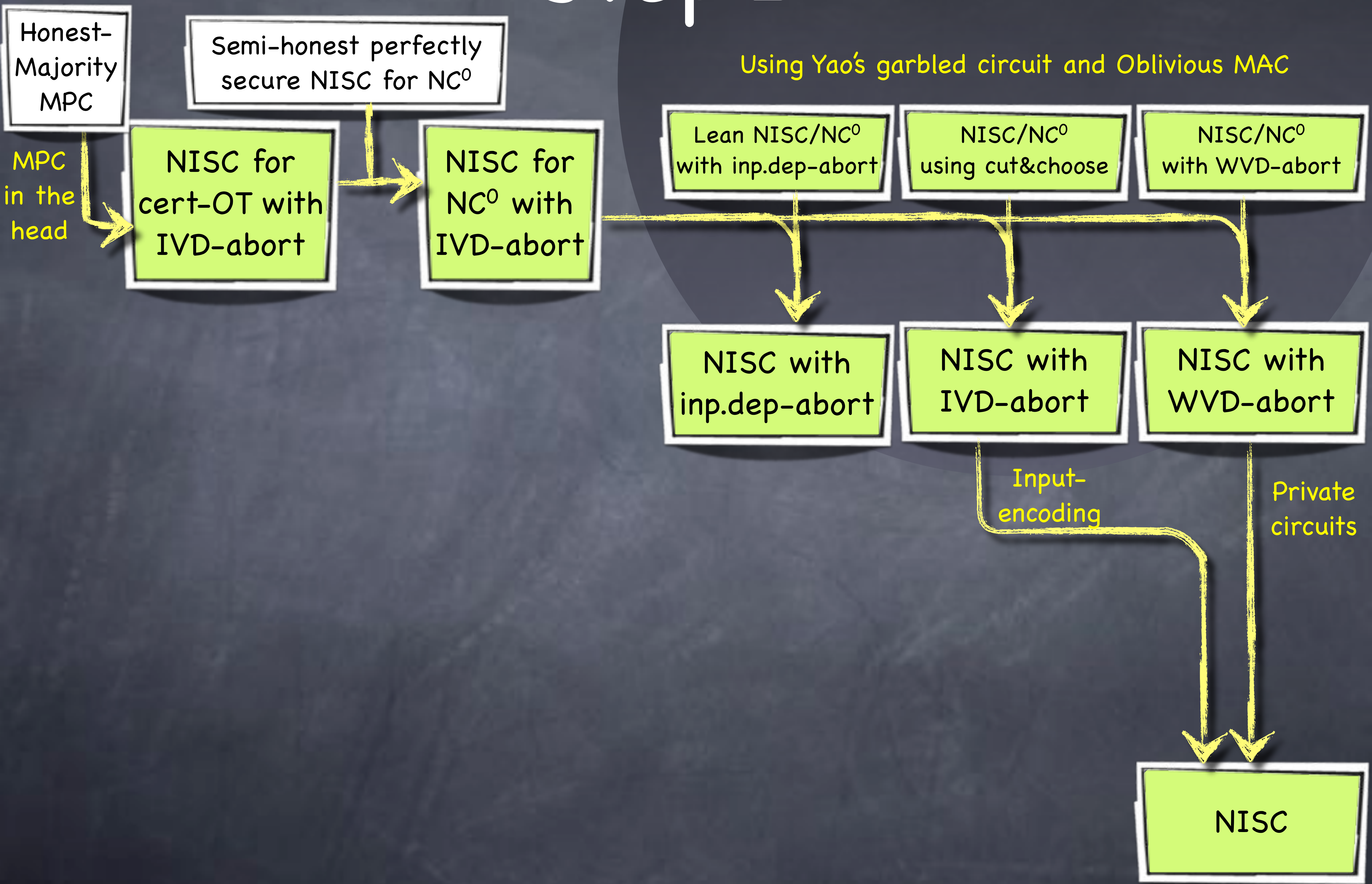
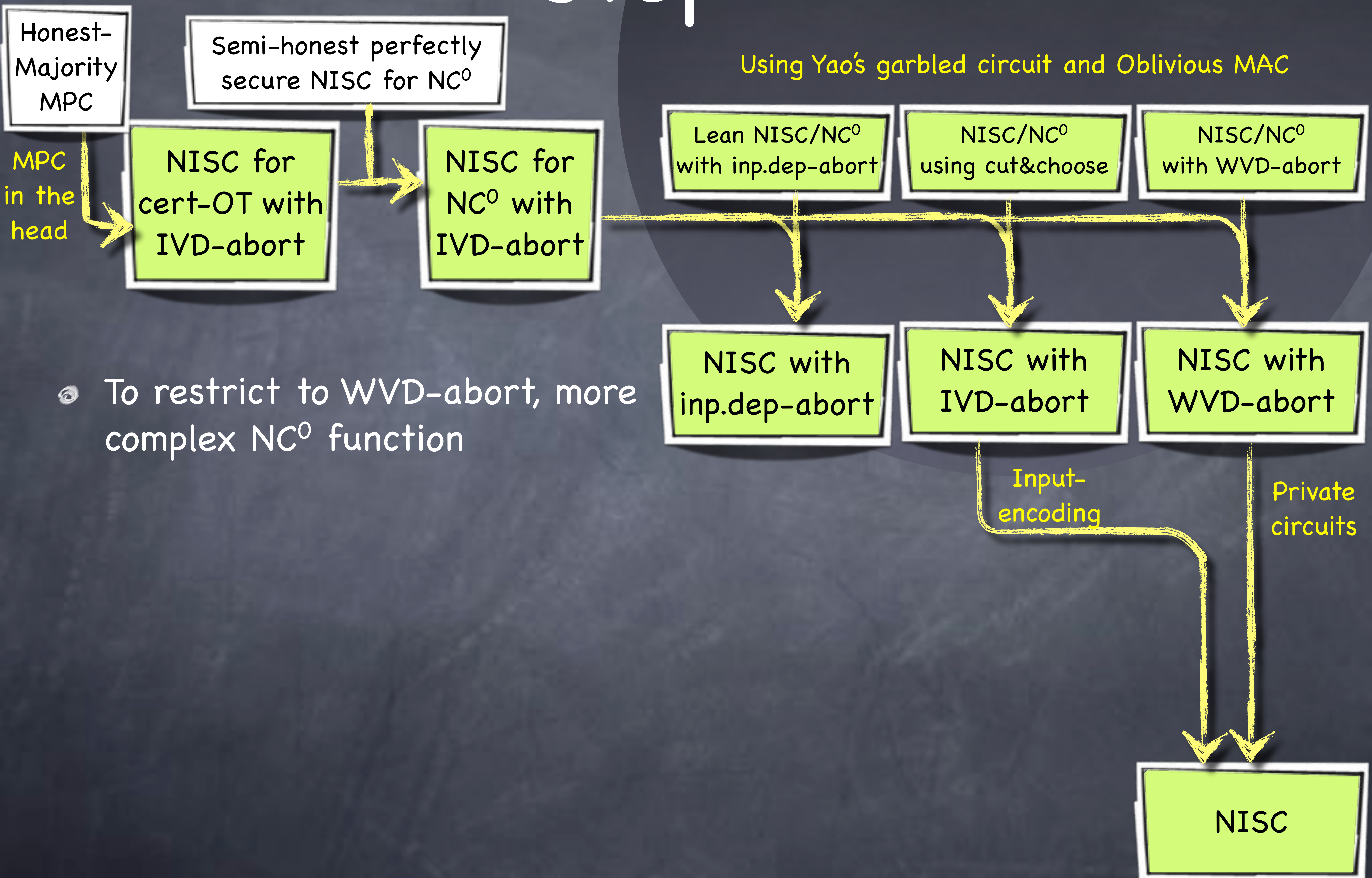
- But if no abort, then throughout the evaluation, for each (G,a′,b′) the c′ value recovered is correct, and hence output is correct
- Input-dependent abort security: since abort can depend on the inputs in a fairly complicated way

Step 2

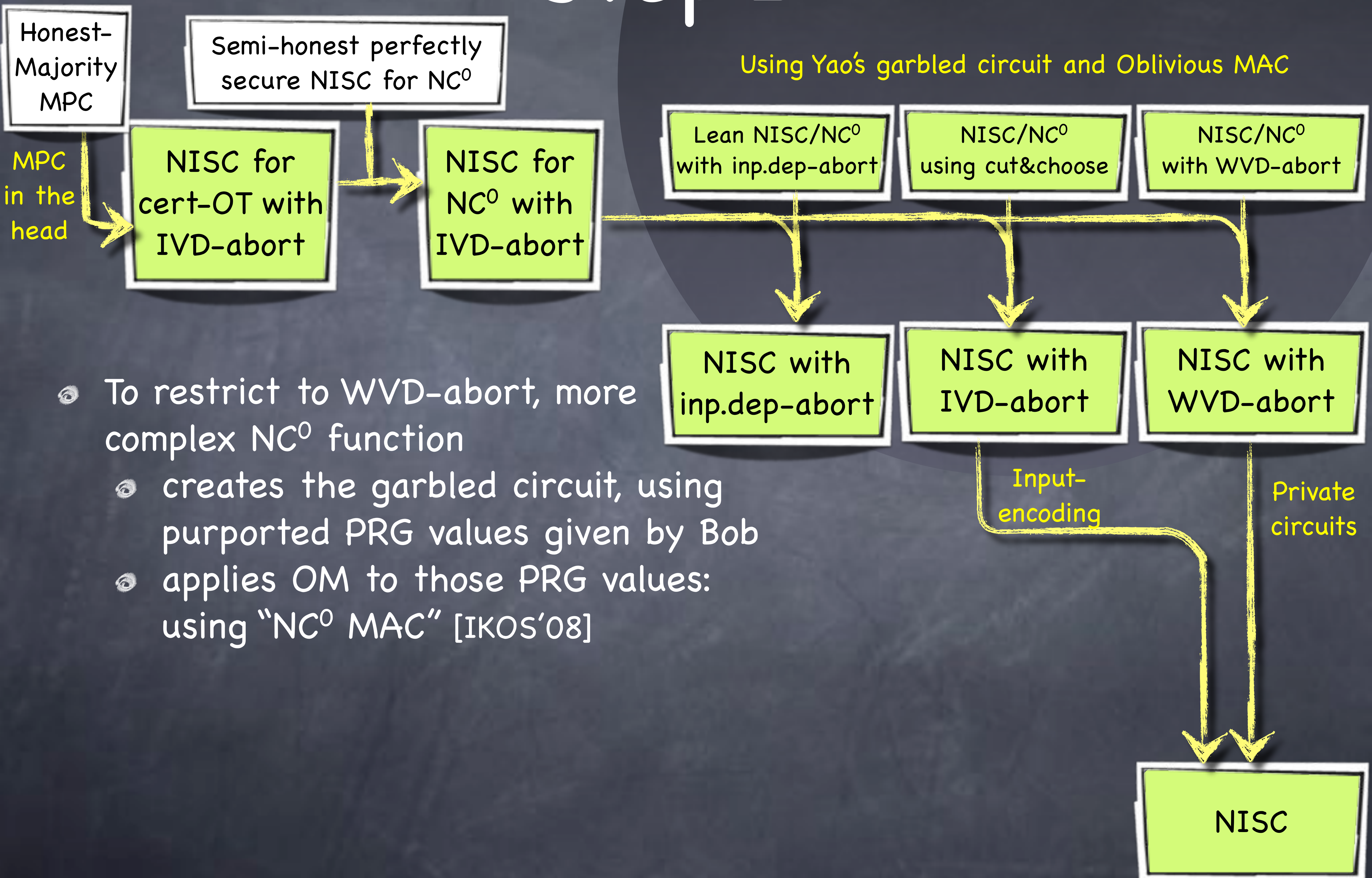

Honest-Majority MPC
MPC in the head
NISC for cert-OT with IVD-abort
Semi-honest perfectly secure NISC for NC^0
NISC for NC^0 with IVD-abort
Using Yao's garbled circuit and Oblivious MAC
Lean NISC/NC^0 with inp.dep-abort
NISC/NC^0 using cut&choose
NISC/NC^0 with WVD-abort
NISC with inp.dep-abort
NISC with IVD-abort
NISC with WVD-abort
Input-encoding
Private circuits
NISC

Step 2



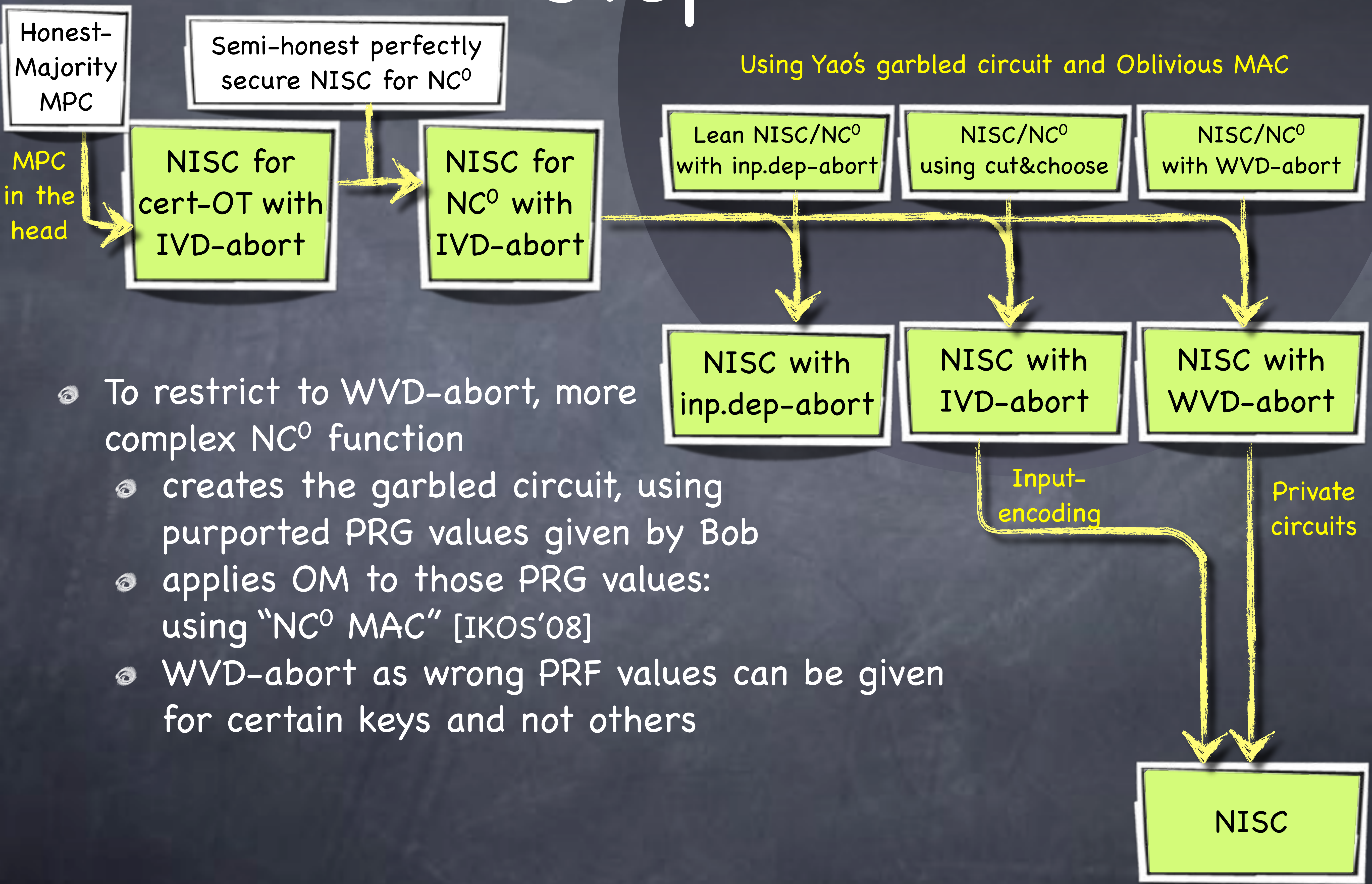
- To restrict to WVD-abort, more complex NC^0 function

Step 2



- To restrict to WVD-abort, more complex NC^0 function
  - creates the garbled circuit, using purported PRG values given by Bob
  - applies OM to those PRG values: using "NC^0 MAC" [IKOS'08]

Step 2



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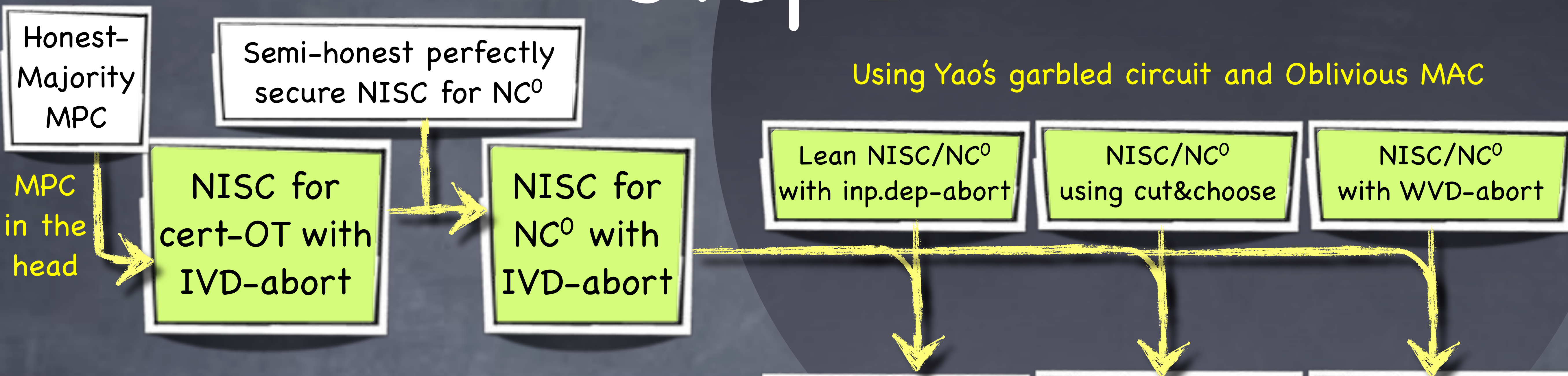

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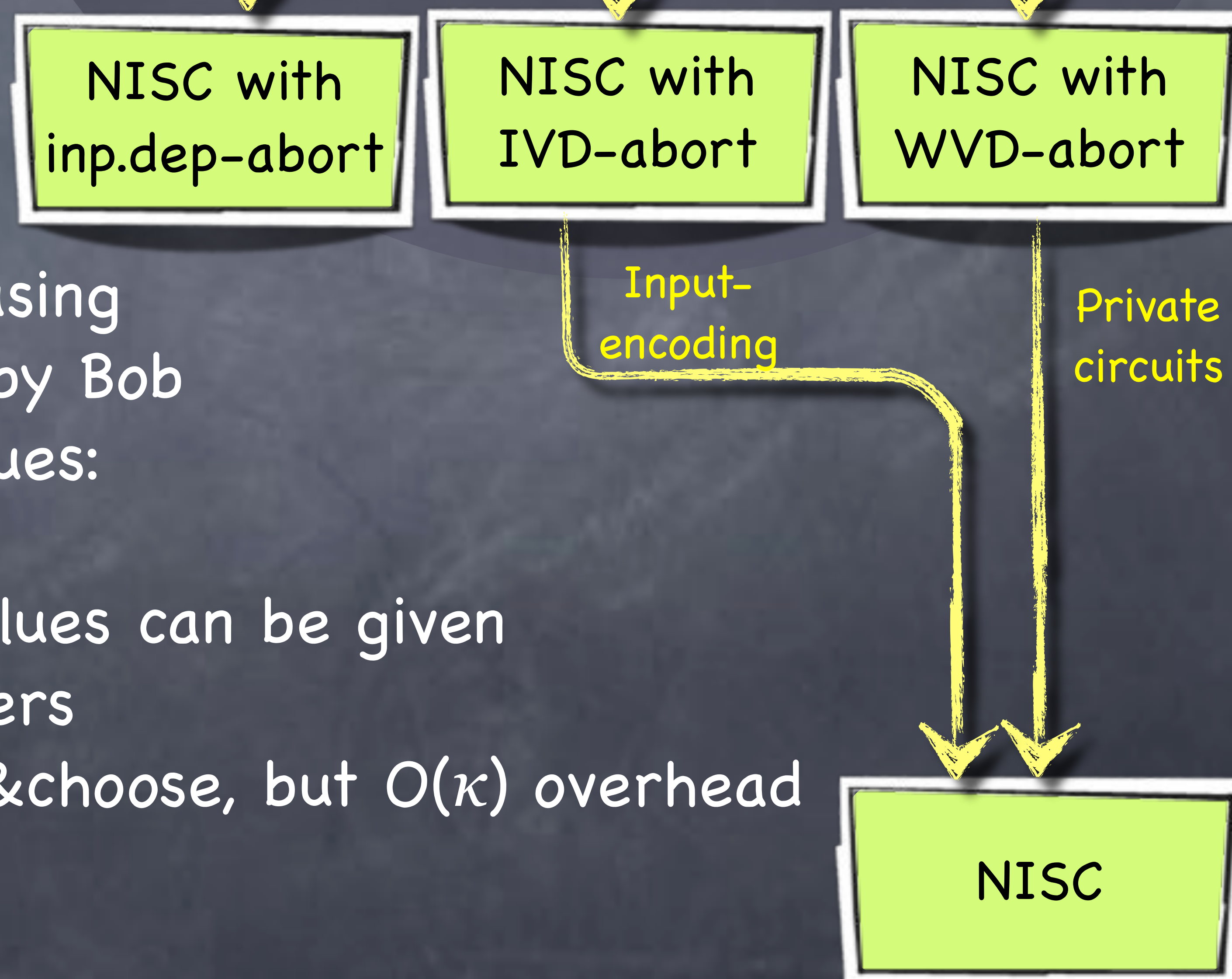
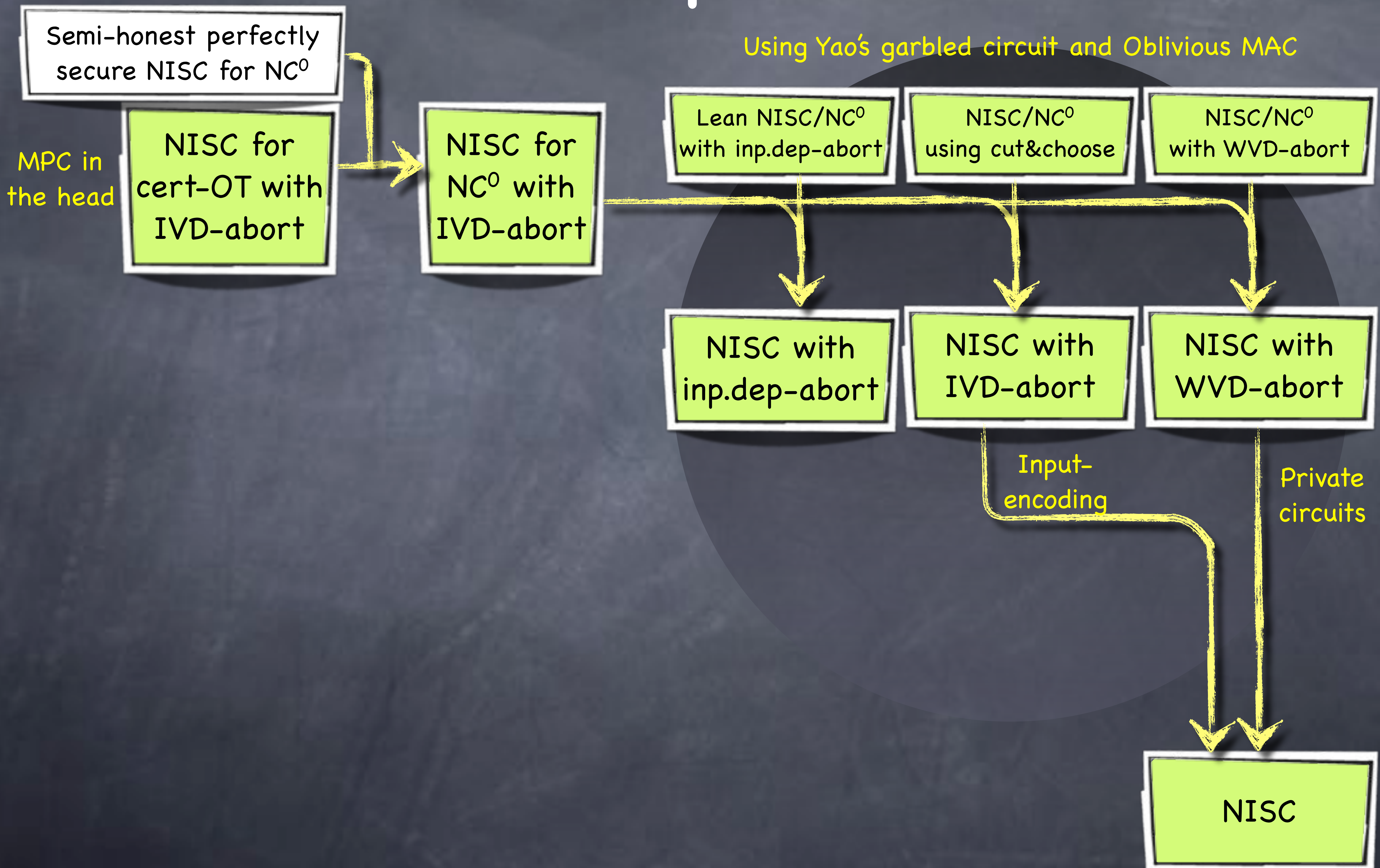
  - applies OM to those PRG values: using "NC^0 MAC" [IKOS'08]
  - WVD-abort as wrong PRF values can be given for certain keys and not others
- Can avoid WVD-abort using cut&choose, but $O(\kappa)$ overhead



Step 3



Semi-honest perfectly secure NISC for NC^0
MPC in the head
NISC for cert-OT with IVD-abort
NISC for NC^0 with IVD-abort
Using Yao's garbled circuit and Oblivious MAC
Lean NISC/NC^0 with inp.dep-abort
NISC/NC^0 using cut&choose
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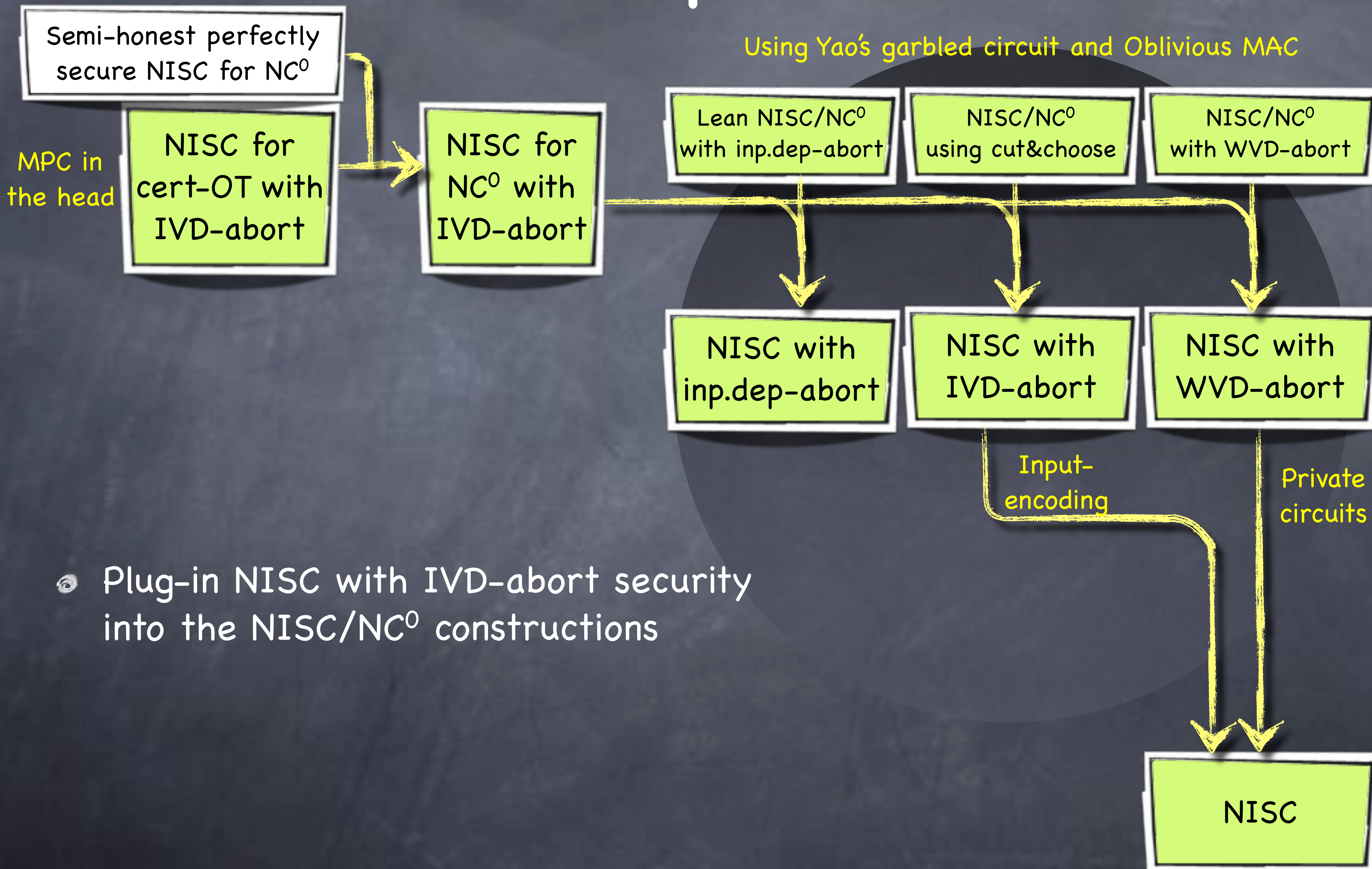
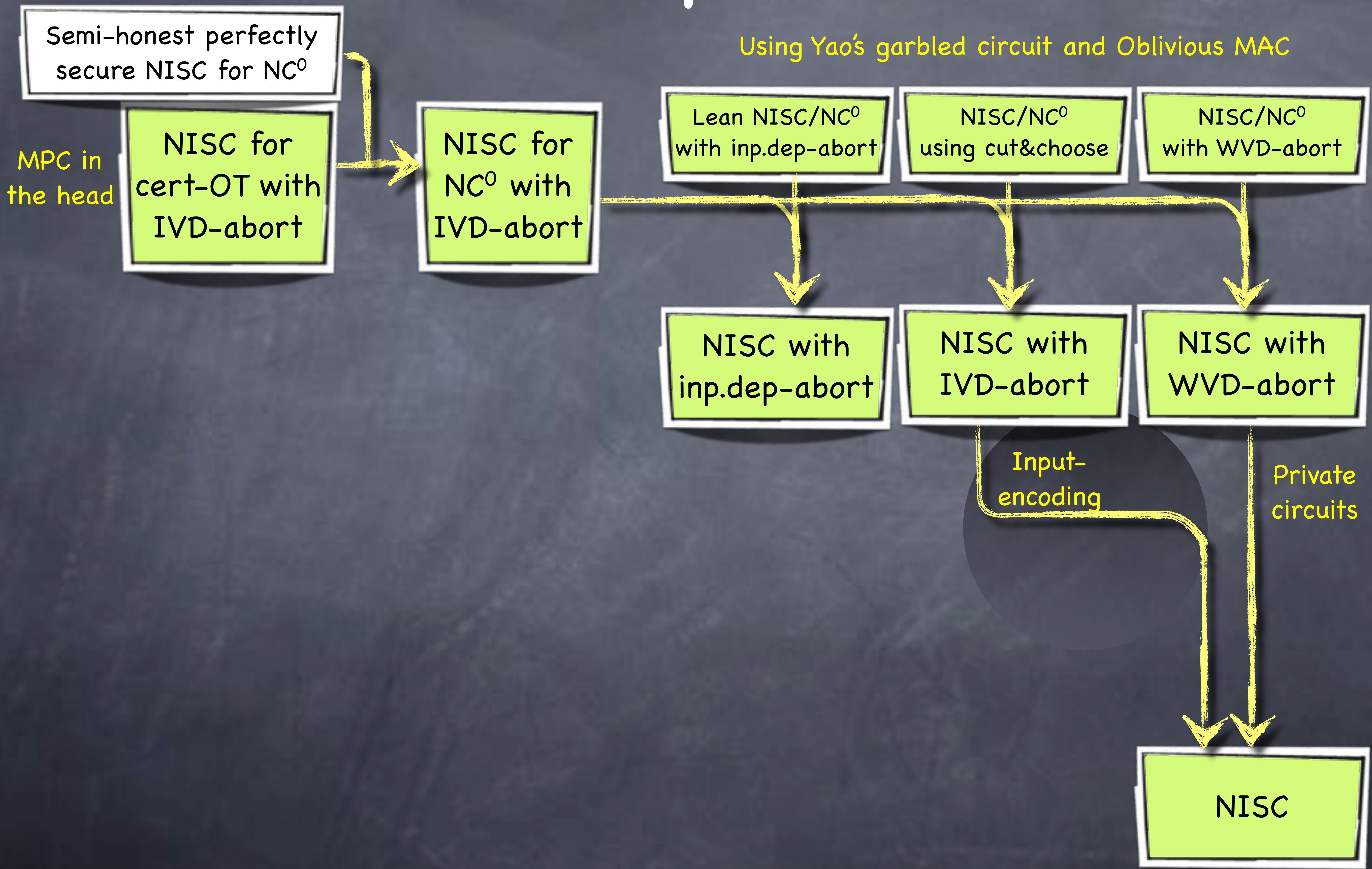
NISC with inp.dep-abort
NISC with IVD-abort
NISC with WVD-abort
Input-encoding
Private circuits
NISC

Step 3



- Plug-in NISC with IVD-abort security into the NISC/NC^0 constructions

Step 4



Semi-honest perfectly secure NISC for NC⁰
MPC in the head
NISC for cert-OT with IVD-abort
NISC for NC⁰ with IVD-abort
Using Yao's garbled circuit and Oblivious MAC
Lean NISC/NC⁰ with inp.dep-abort
NISC/NC⁰ using cut&choose
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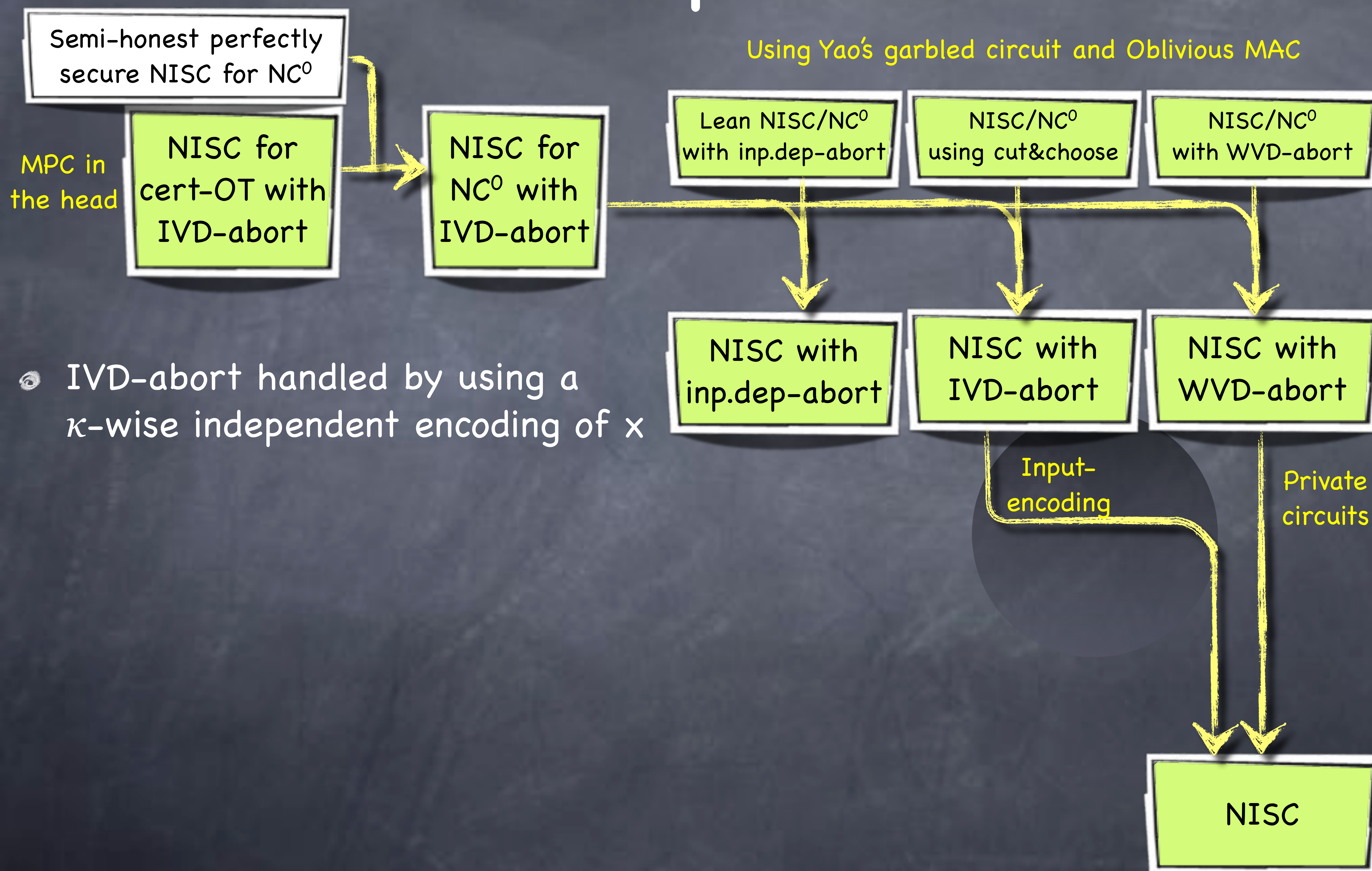
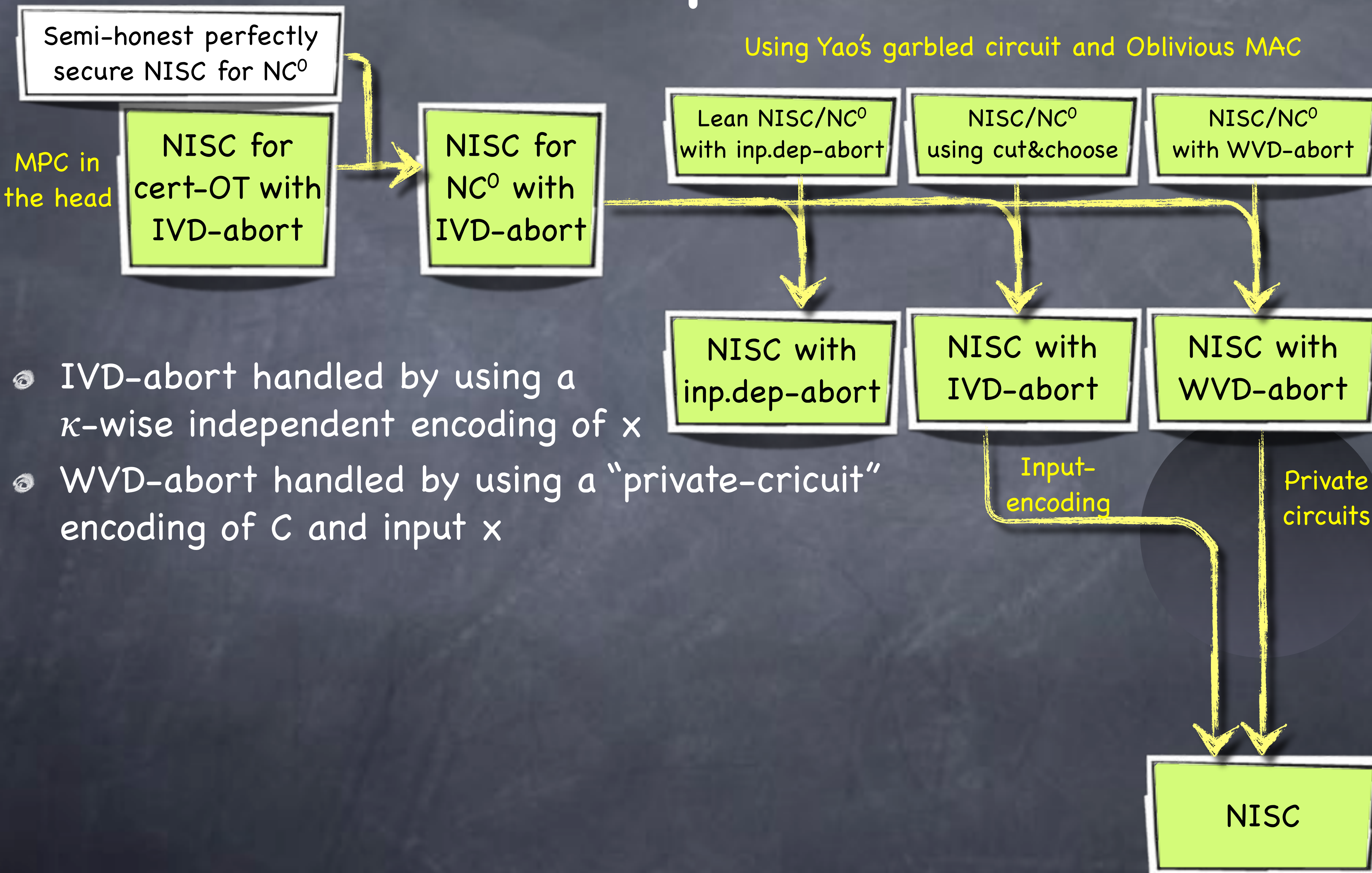
NISC with IVD-abort
NISC with WVD-abort
Input-encoding
Private circuits
NISC

Step 4



- IVD-abort handled by using a κ-wise independent encoding of x

Step 4



- IVD-abort handled by using a κ-wise independent encoding of x
- WVD-abort handled by using a "private-cricuit" encoding of C and input x

Step 4

Semi-honest perfectly secure NISC for NC^0

MPC in the head

NISC for cert-OT with IVD-abort

NISC for NC^0 with IVD-abort

Using Yao's garbled circuit and Oblivious MAC

Lean NISC/NC^0 with inp.dep-abort

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NISC with IVD-abort

NISC with WVD-abort

Input-encoding

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NISC

- IVD-abort handled by using a κ-wise independent encoding of x
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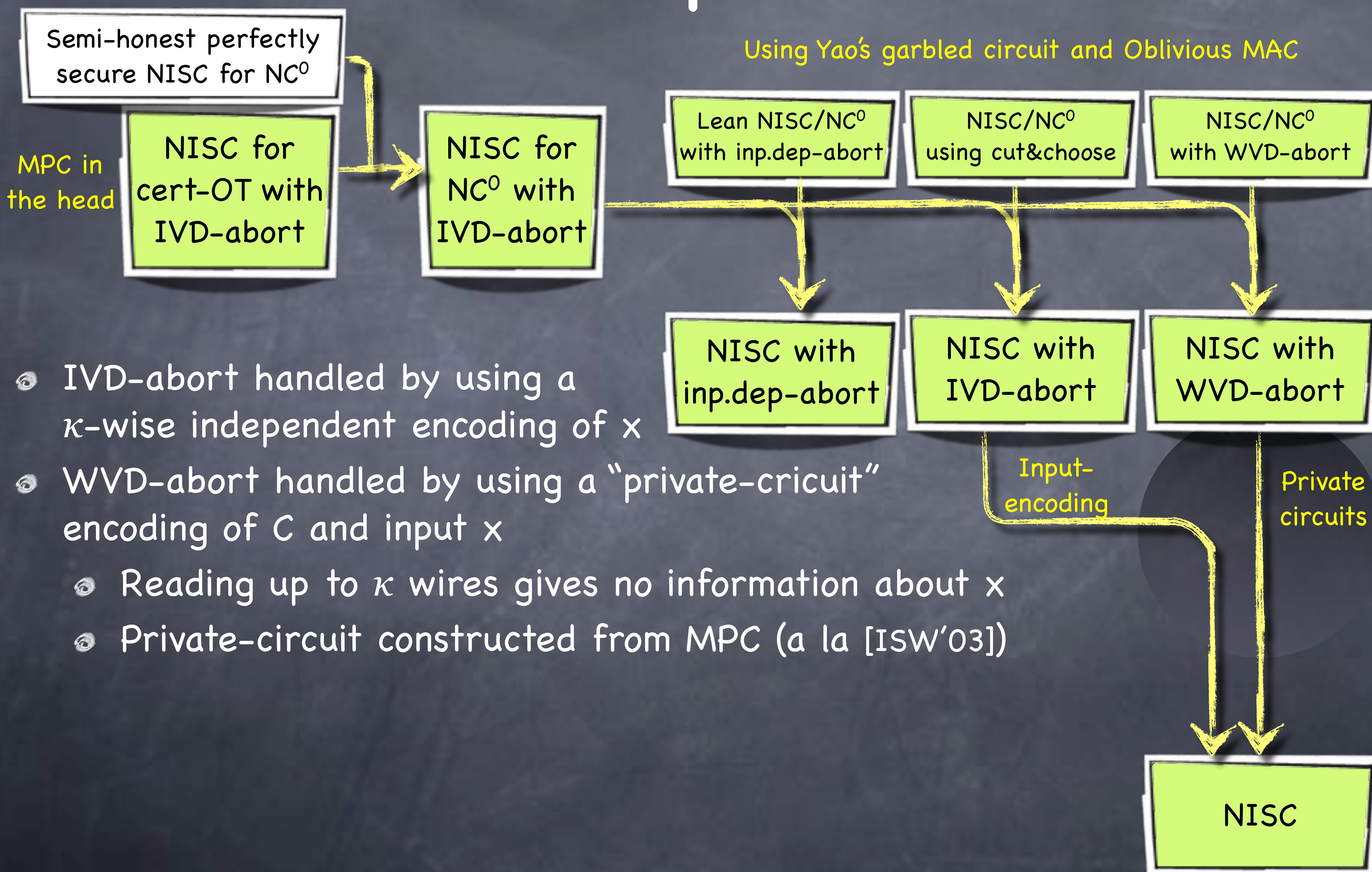
Step 4



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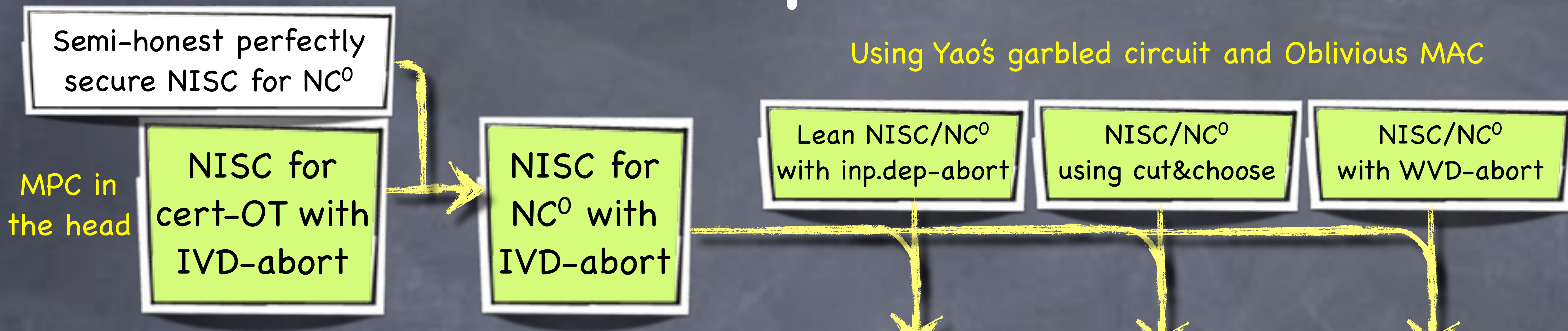
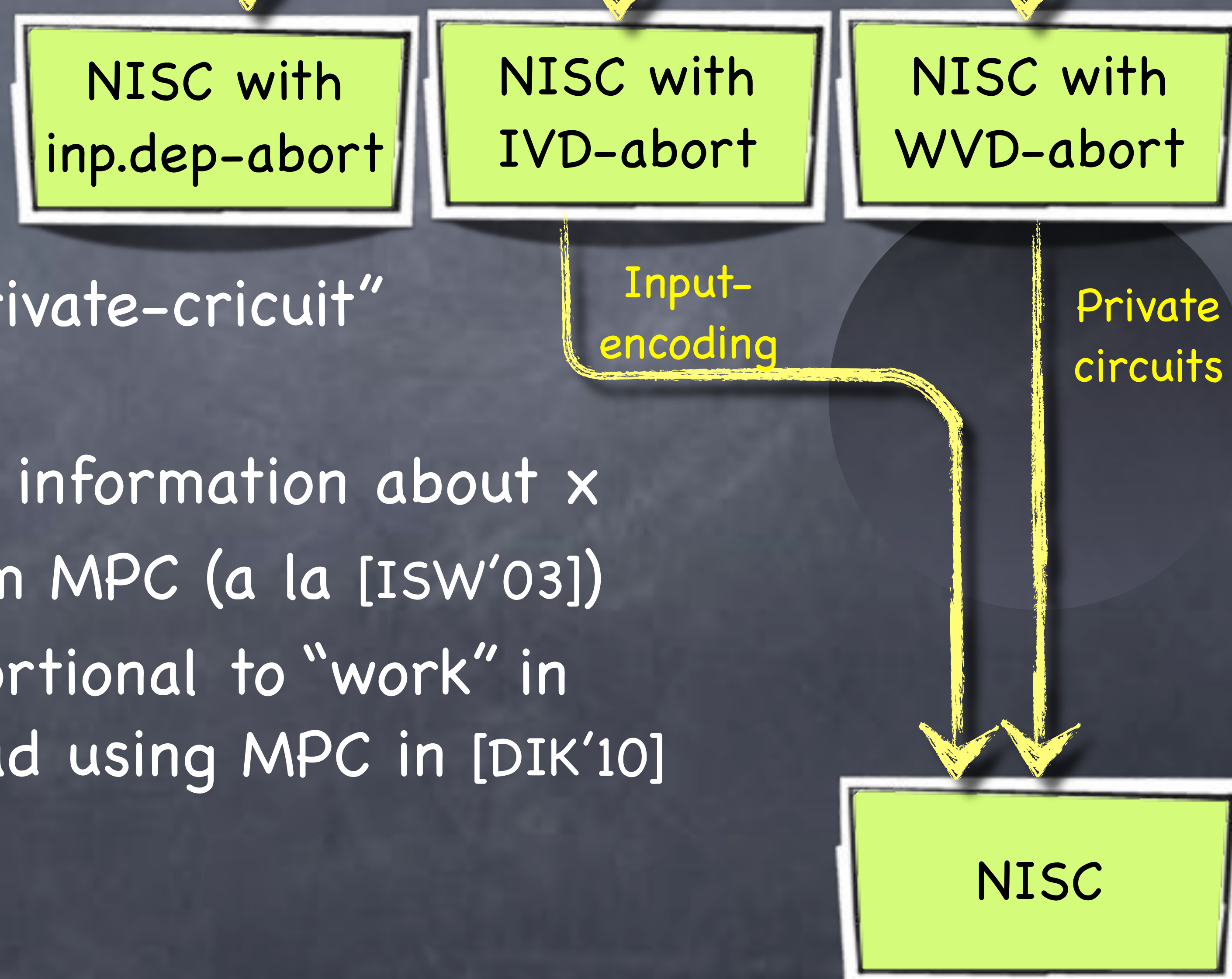
Step 4





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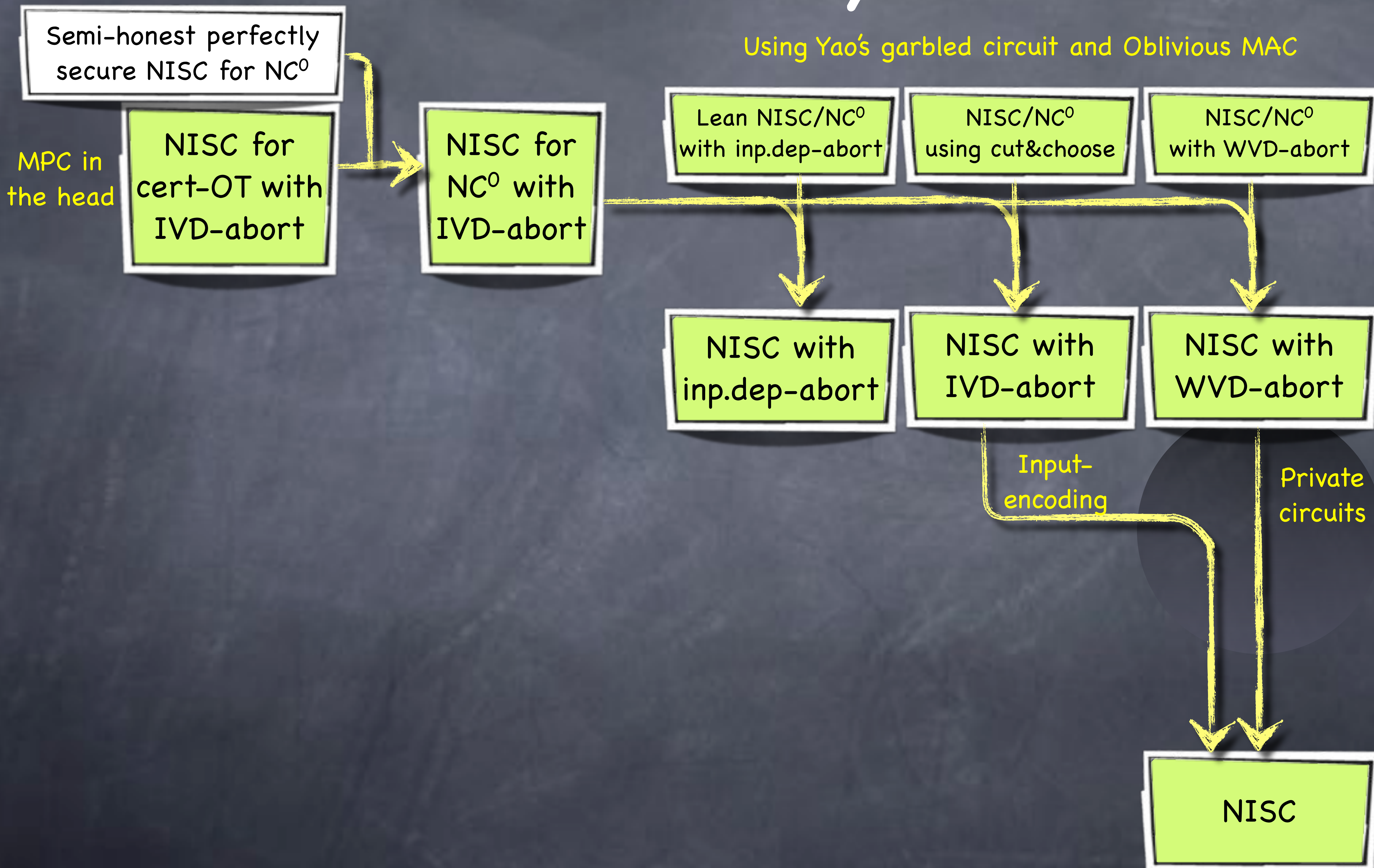
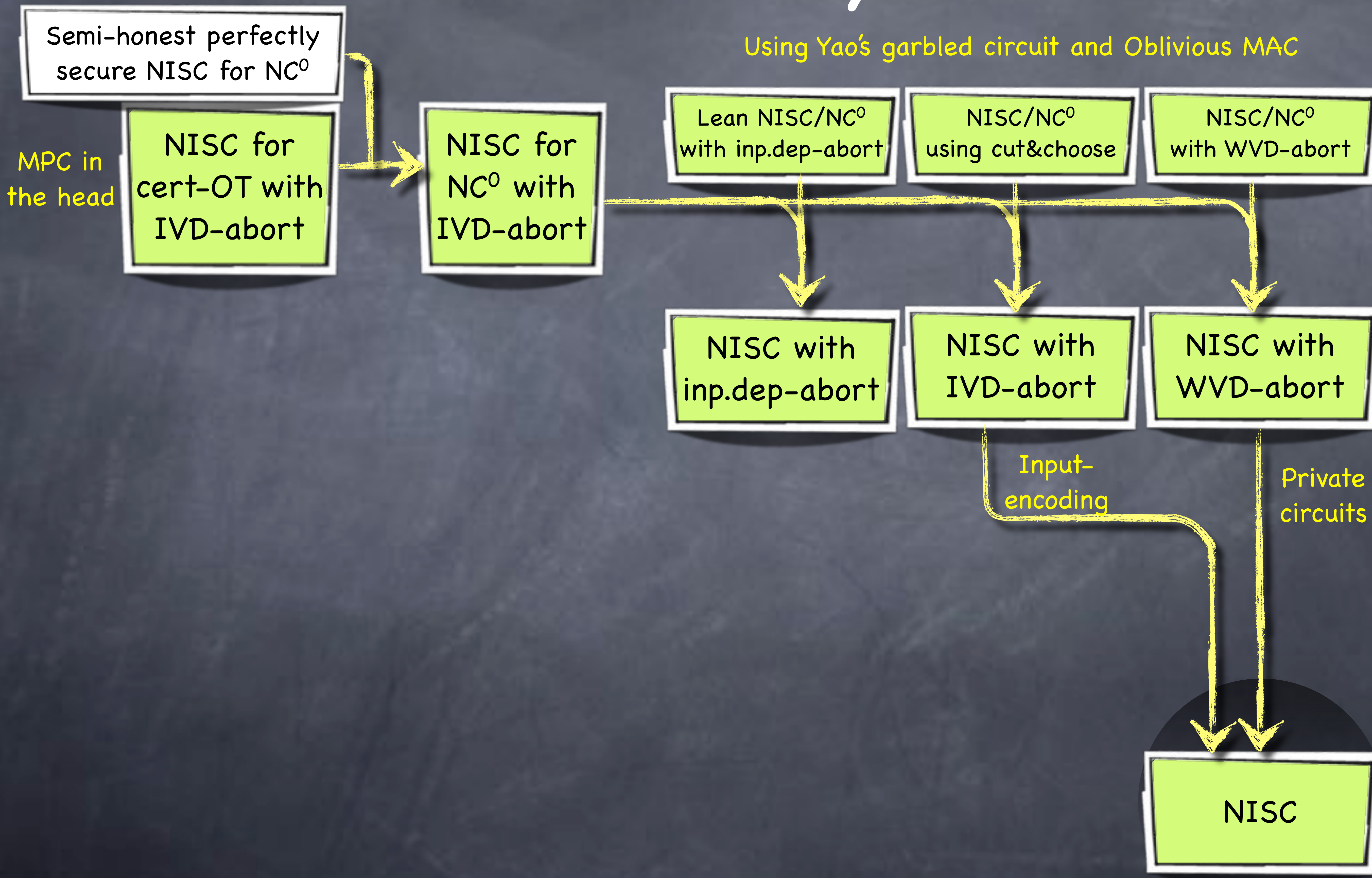
  - Reading up to κ wires gives no information about x
  - Private-circuit constructed from MPC (a la [ISW'03])
    - Size of private-circuit proportional to "work" in the MPC. polylog(κ) overhead using MPC in [DIK'10]

Summary


Semi-honest perfectly secure NISC for NC^0
Using Yao's garbled circuit and Oblivious MAC
MPC in the head
NISC for cert-OT with IVD-abort
NISC for NC^0 with IVD-abort
Lean NISC/NC^0 with inp.dep-abort
NISC/NC^0 using cut&choose
NISC/NC^0 with WVD-abort
NISC with inp.dep-abort
NISC with IVD-abort
NISC with WVD-abort
Input-encoding
Private circuits
NISC

Summary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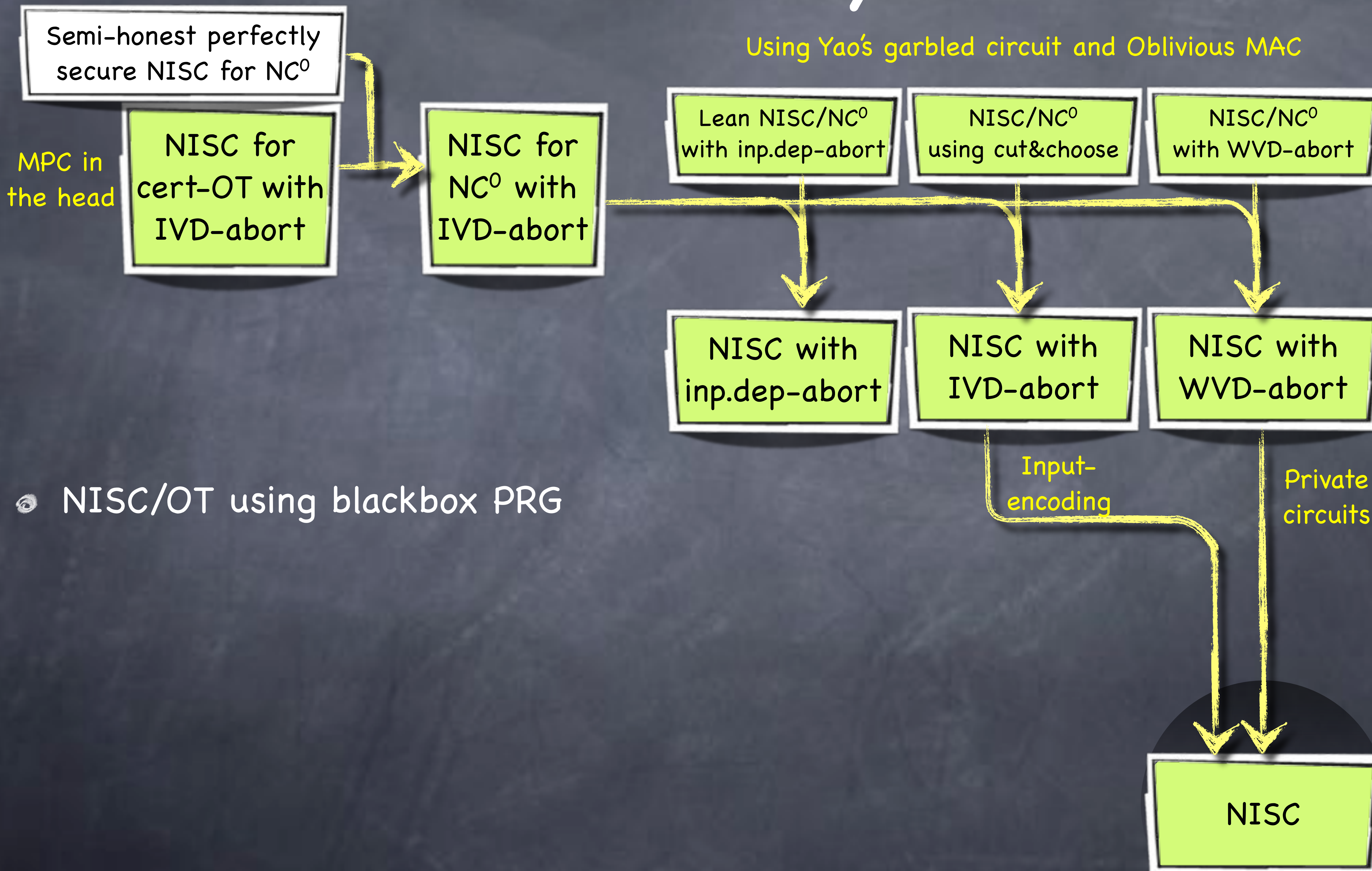
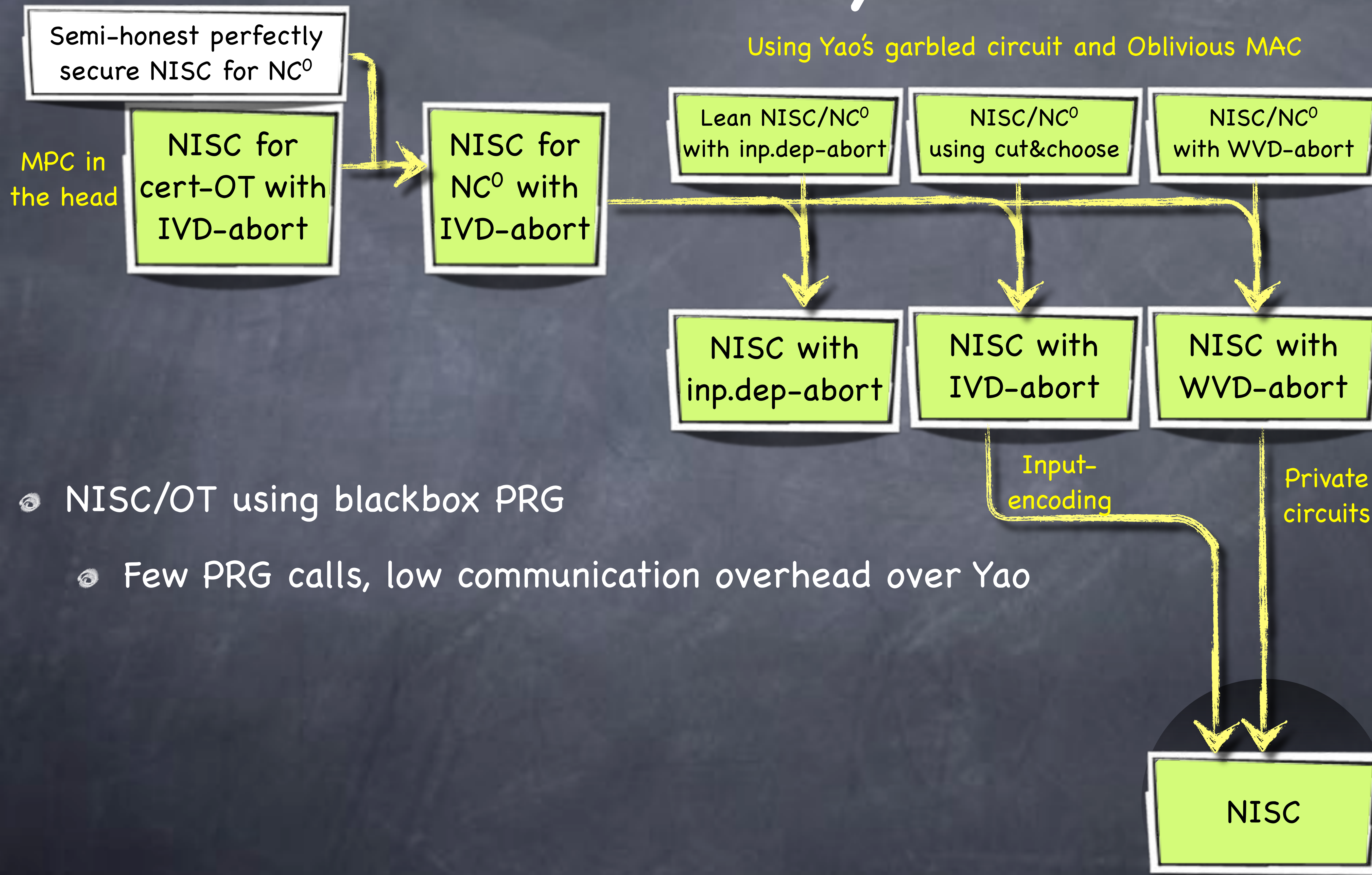


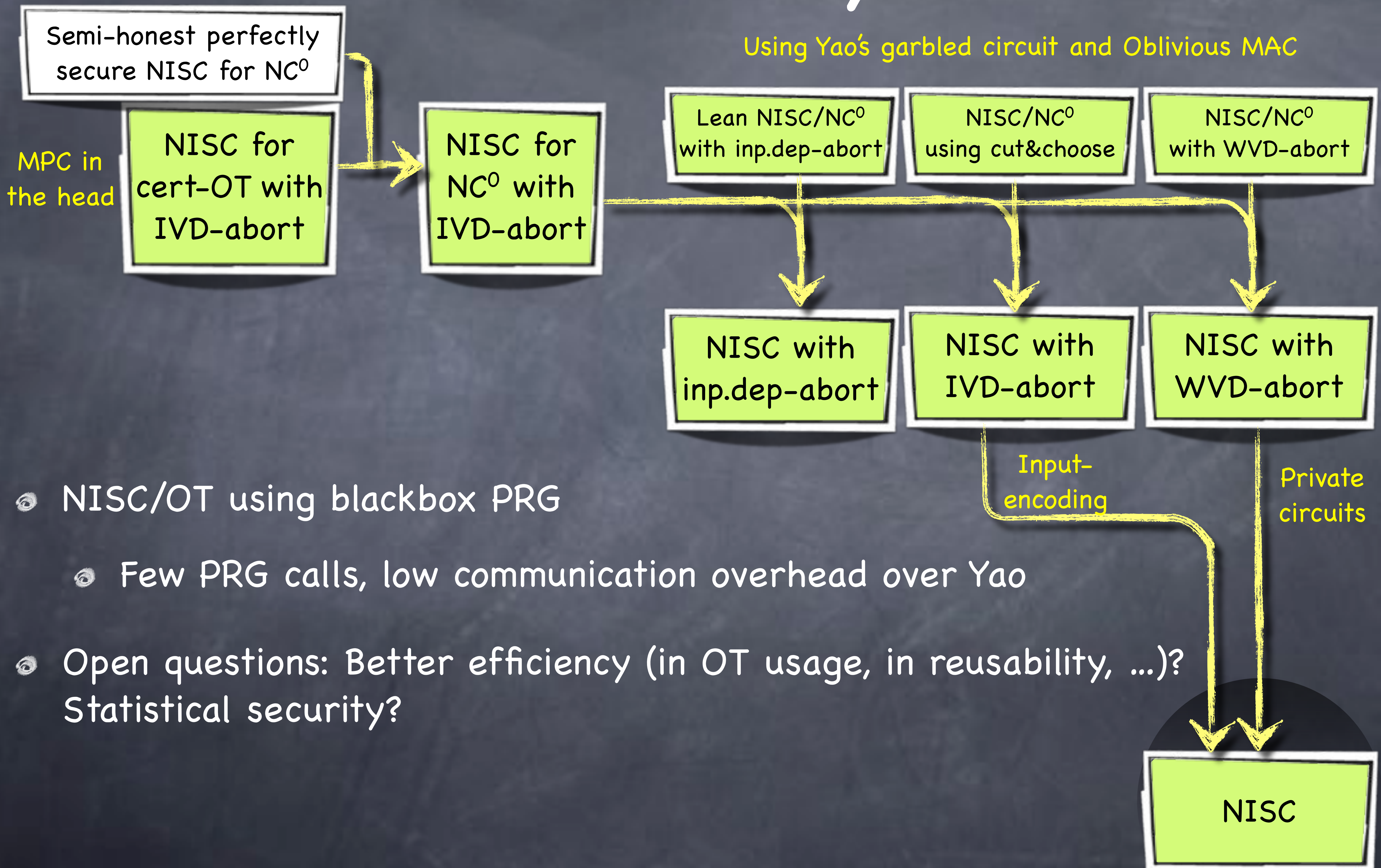
- NISC/OT using blackbox PRG

Summary



- NISC/OT using blackbox PRG
  - Few PRG calls, low communication overhead over Yao

Summary



- NISC/OT using blackbox PRG
  - Few PRG calls, low communication overhead over Yao
- Open questions: Better efficiency (in OT usage, in reusability, ...)? Statistical security?