A Practical-Time Related-Key Boomerang Attack on MMB

Tomer Ashur Orr Dunkelman

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7. Possible extenstions of the attack.

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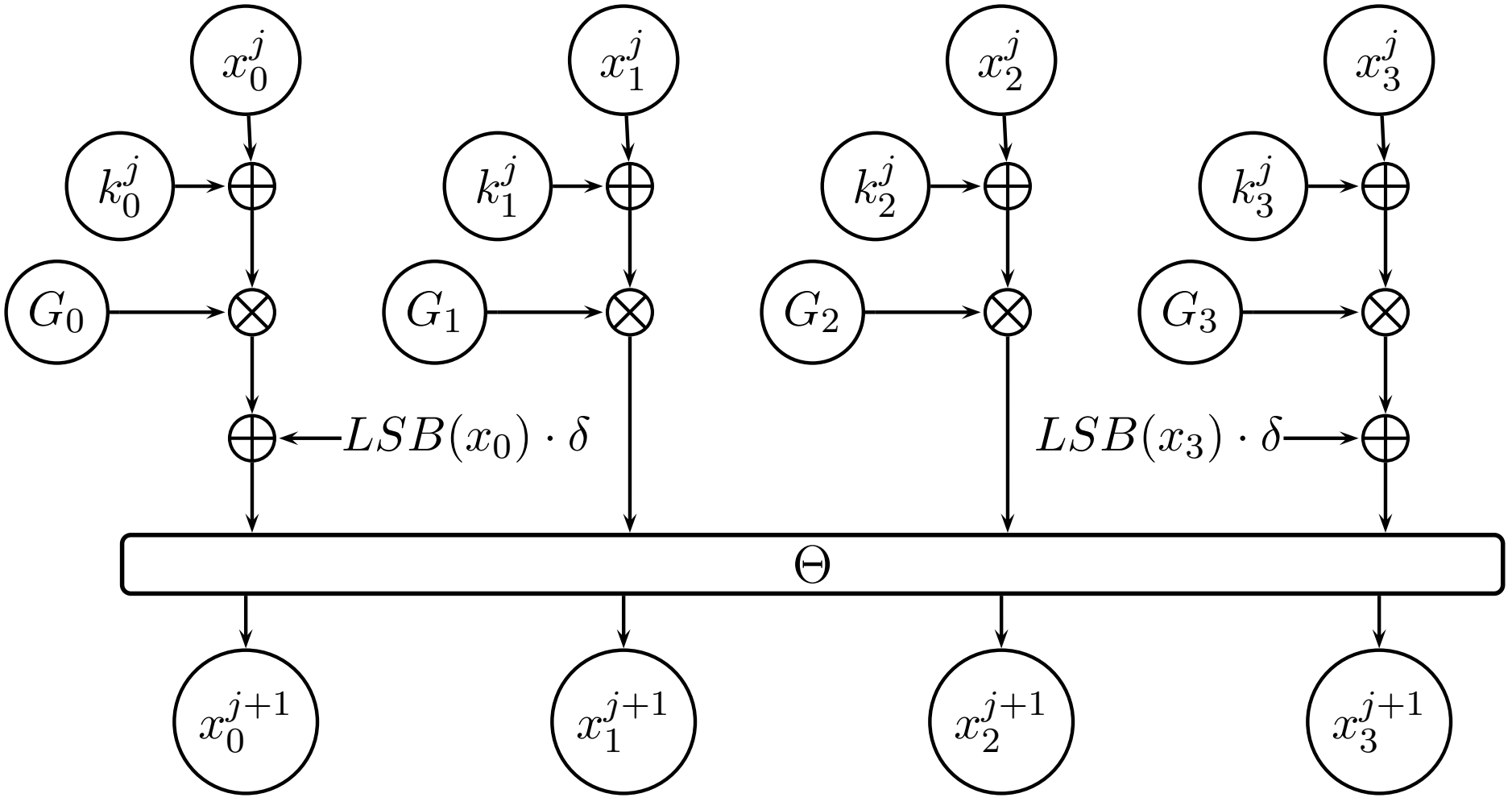
  - θ - matrix multiplication $(x_{i-1} \oplus x_i \oplus x_{i+1})$.

MMB's Round Function



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- Related-key boomerang attack[K+04,K+05,BDK05]

Previous Work

- 2-round differential with probability 1 [WNS09]:

$$(0,\bar{0},\bar{0},0) \xrightarrow{\sigma[\mathrm{k}^0]} (0,\bar{0},\bar{0},0) \xrightarrow{\gamma} (0,\bar{0},\bar{0},0) \xrightarrow{\eta} (0,\bar{0},\bar{0},0) \xrightarrow{\theta} (\bar{0},0,0,\bar{0})$$
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- 5-round sandwich distinguisher with probability 1 [J+11].
- Full key recovery with time complexity of 2^{40} [J+11].

Description of the Differential Characteristics

3-round related-key differential characteristic with probability 1:
$\triangle =$
$(0, 0, \bar{0}, \bar{0}) \xrightarrow{(0,0,\bar{0},\bar{0})}$
$(\delta, \bar{0}, \delta, \bar{\delta}) = \triangle^*.$

Full Description

One additional round can be prepended:
$(X, \bar{0}, 0, \bar{0}) \rightarrow \triangle$

4-round related-key differential characteristic with probability 1:
$\bigtriangledown^* =$
$(0, 0, \bar{0}, 0) \xrightarrow{(0,0,\bar{0},0)}$
$(\bar{\delta}, \bar{\delta}, 0, \bar{\delta}) = \bigtriangledown$

Full Description

One additional round can be prepended:
$(0, \bar{0}, \bar{0}, Y) \rightarrow \bigtriangledown^*$

2-round related-key differential characteristic with probability 1:
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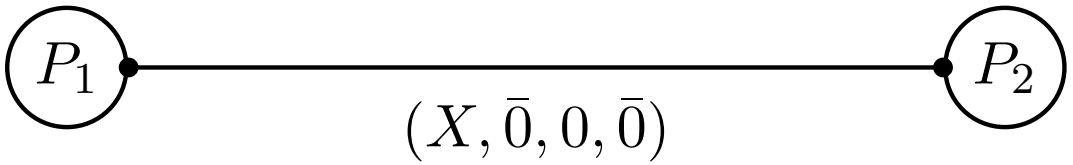
Full Description

Description of B_0



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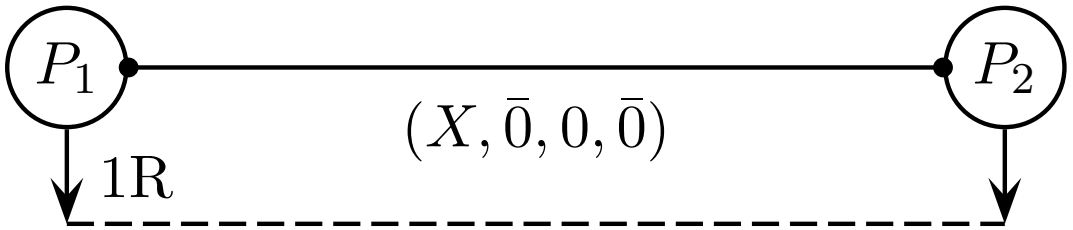

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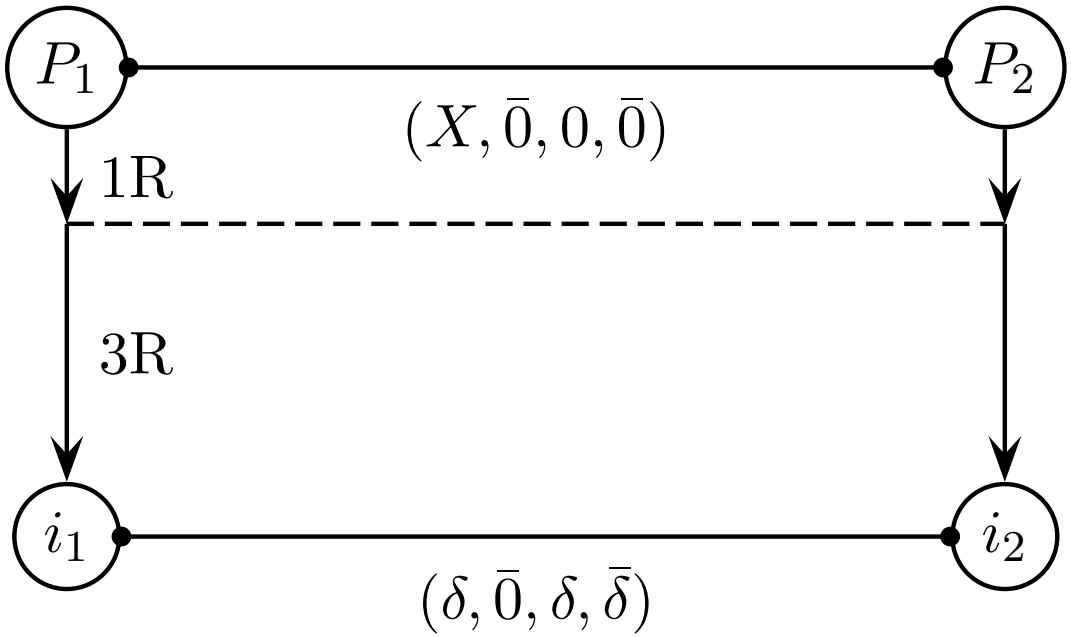

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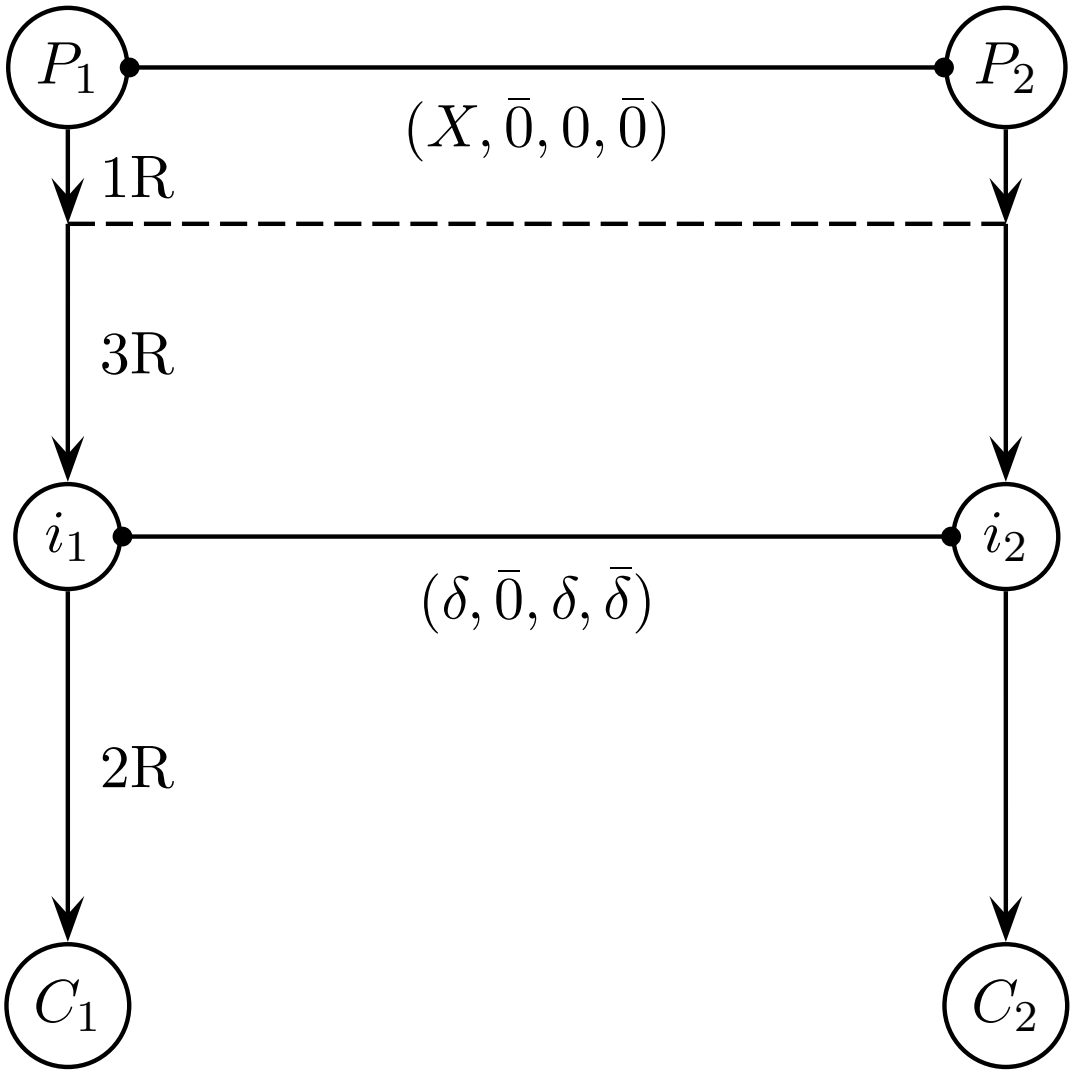

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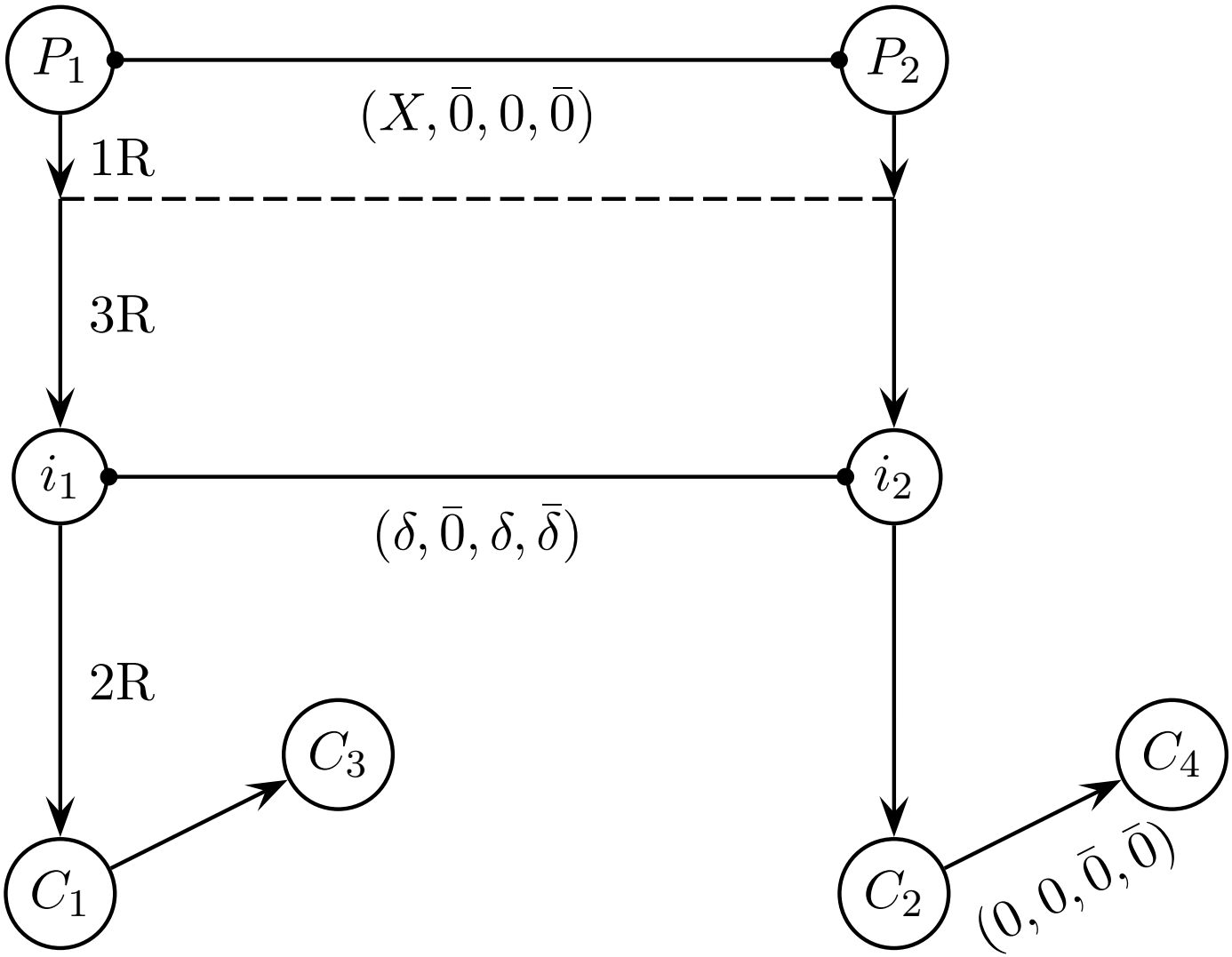

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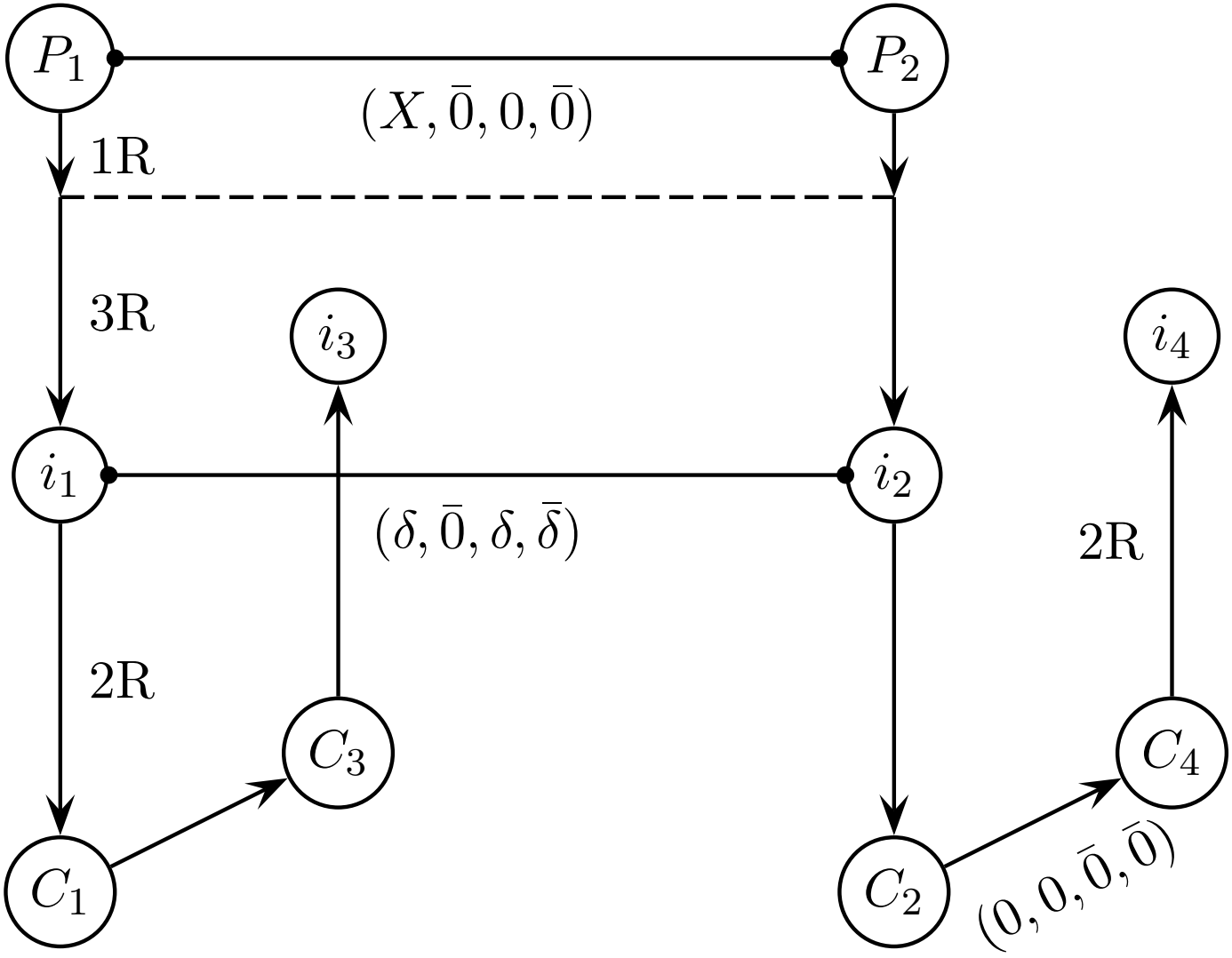

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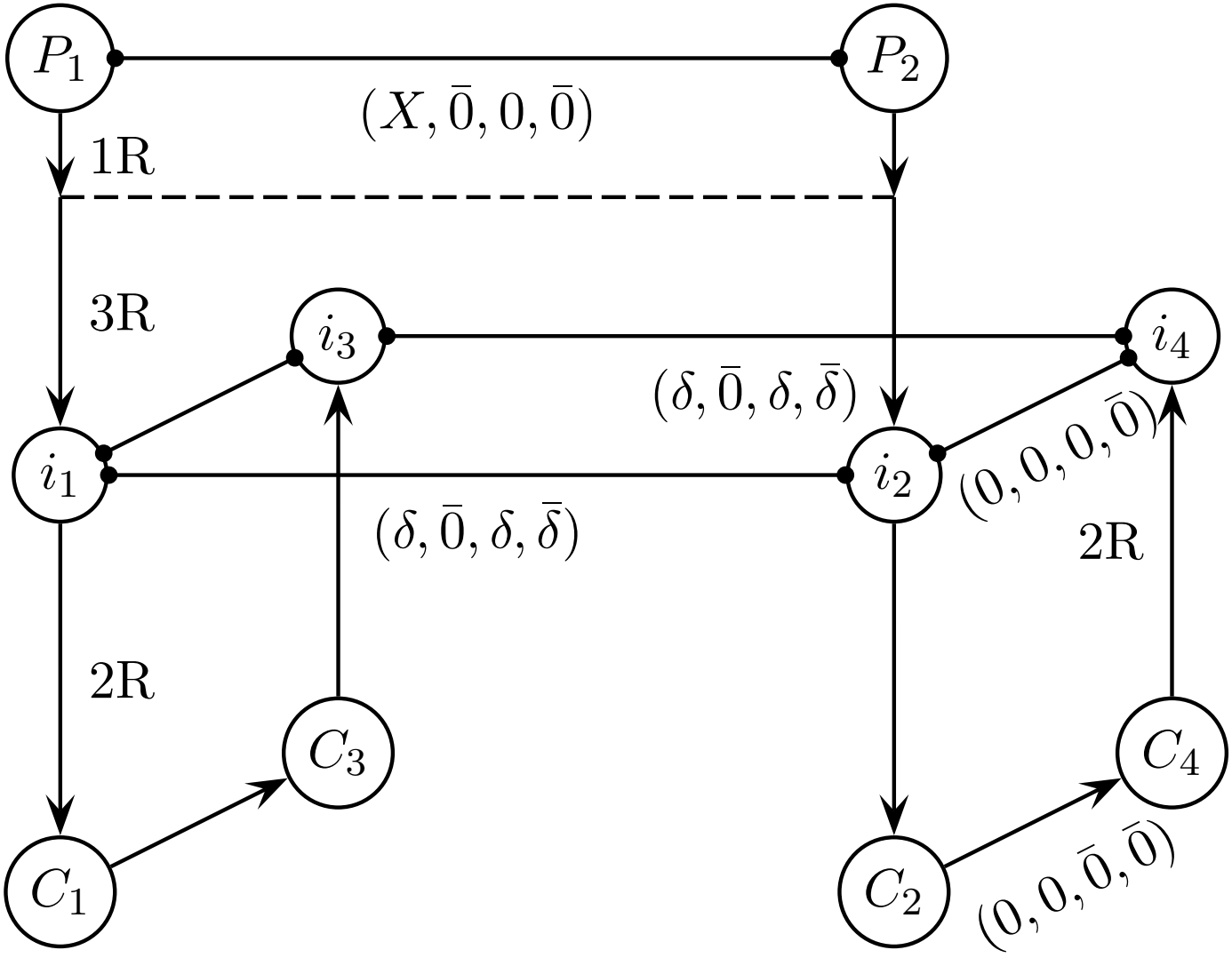

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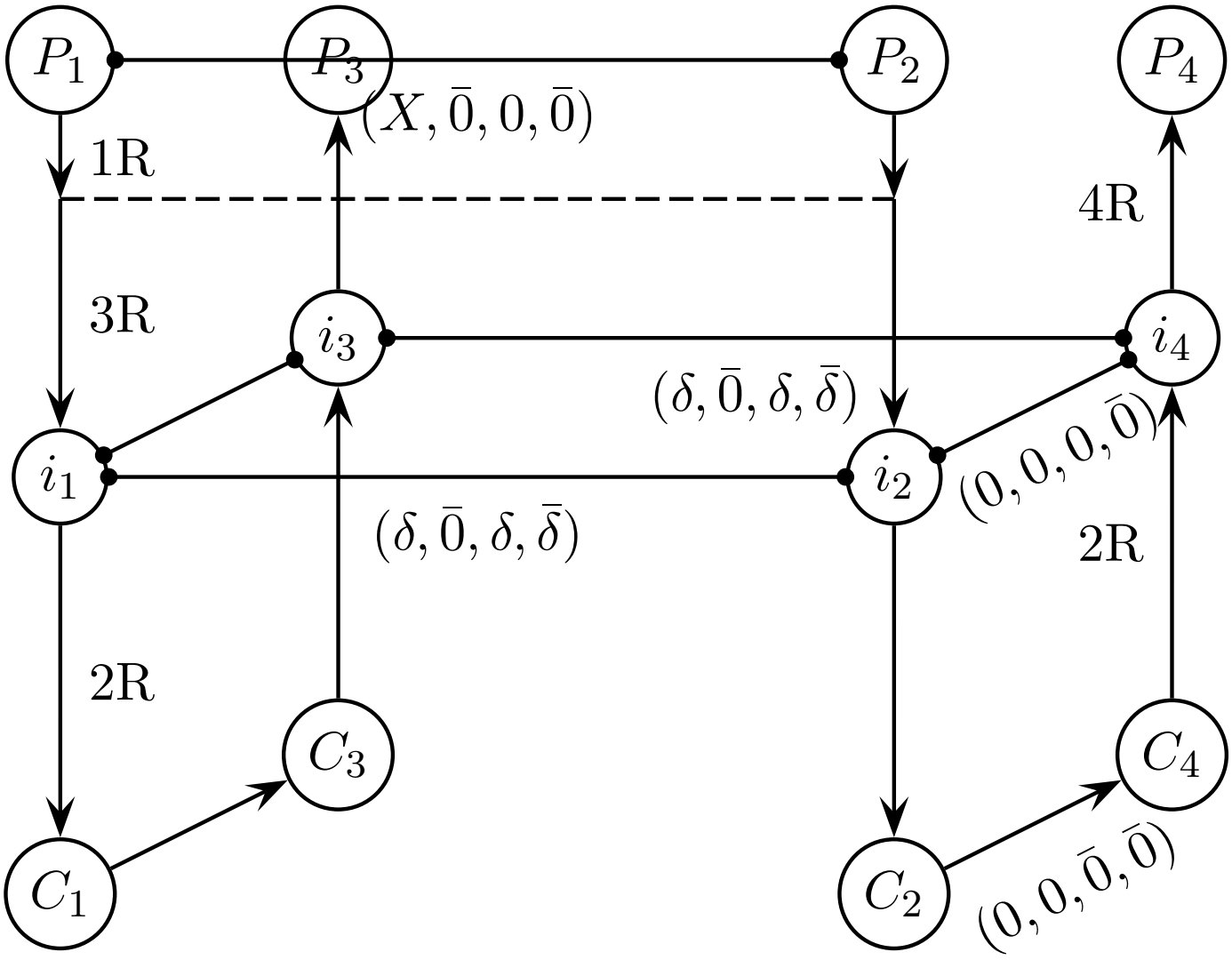

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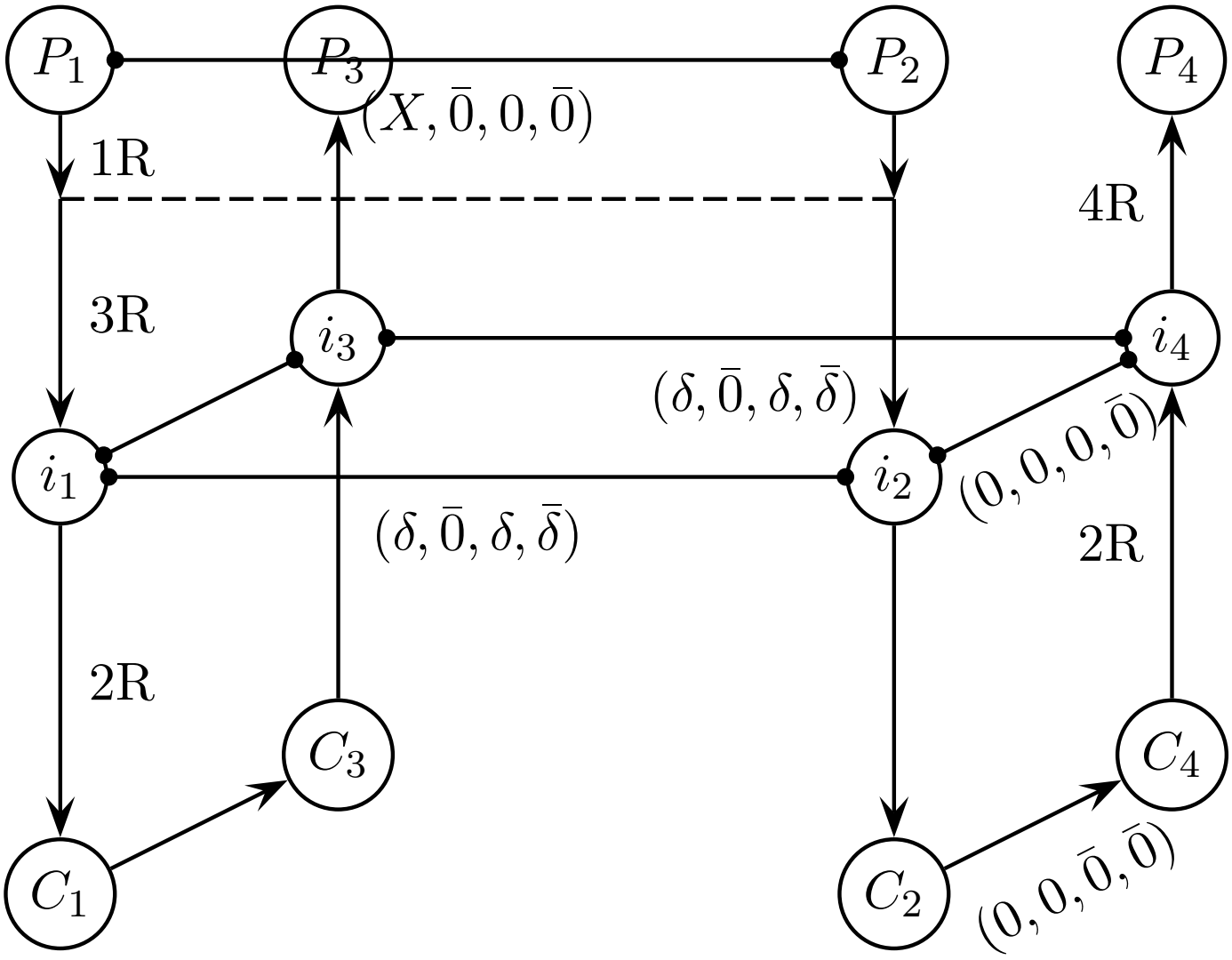

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- It is expected that 4 right pairs will be identified.

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- Verify using another right pair.

Recovering More Key Bits

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- Due to the differential characteristic, the values entering γ in the fifth round are known to be $(\overline{\delta}, \overline{\delta}, 0, \overline{\delta})$.
- By using the two known key words, and iterating the value of k_2^6 we can reverse the last encryption round. The right key word (and its inverse) will lead to $\overline{\delta}$ in the second word.

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- To distinguish the real key from its negation, this phase must try all possible assignments.

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- Data: $2 \cdot 2 \cdot 2 \cdot 2^{17} = 2^{20}$
- Related-keys: 4

Experimental Verification

- All attacks has been verified using a hybrid C and Python code.
- The attack has a success rate of 98%.
- It takes less than 15 minutes on average to recover the full key of MMB.

Improvements

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- Recovering 31 key bits for a variant of MMB with 9 rounds.
- Time memory trade-off.

Thank you for your time. Questions?

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Back

Full Description of $\nabla^* \rightarrow \nabla$

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$$\xrightarrow[(0,0,0,\bar{0})]{\sigma[\mathrm{k}^4]} (\bar{0},0,0,0) \xrightarrow{\gamma} (\bar{0},0,0,0) \xrightarrow{\eta} (\bar{\delta},0,0,0) \xrightarrow{\theta} (\bar{\delta},\bar{\delta},0,\bar{\delta})$$

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Full Description of $\tau \rightarrow \tau^*$

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$$\xrightarrow[(0,0,\bar{0},0)]{\sigma[\mathrm{k}^5]} \xrightarrow{\gamma} (0,0,\bar{0},0) \xrightarrow{\eta} (0,0,\bar{0},0) \xrightarrow{\theta} (0,\bar{0},\bar{0},\bar{0}) = \tau^*$$

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