Non-malleable Codes against Lookahead Tampering

Divya Gupta[1], Hemanta K. Maji[2], Mingyuan Wang[2]

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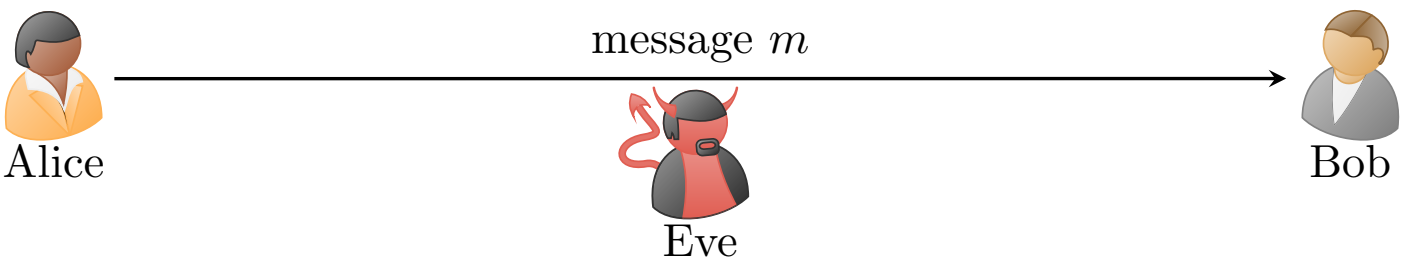
Non-malleable message transmission



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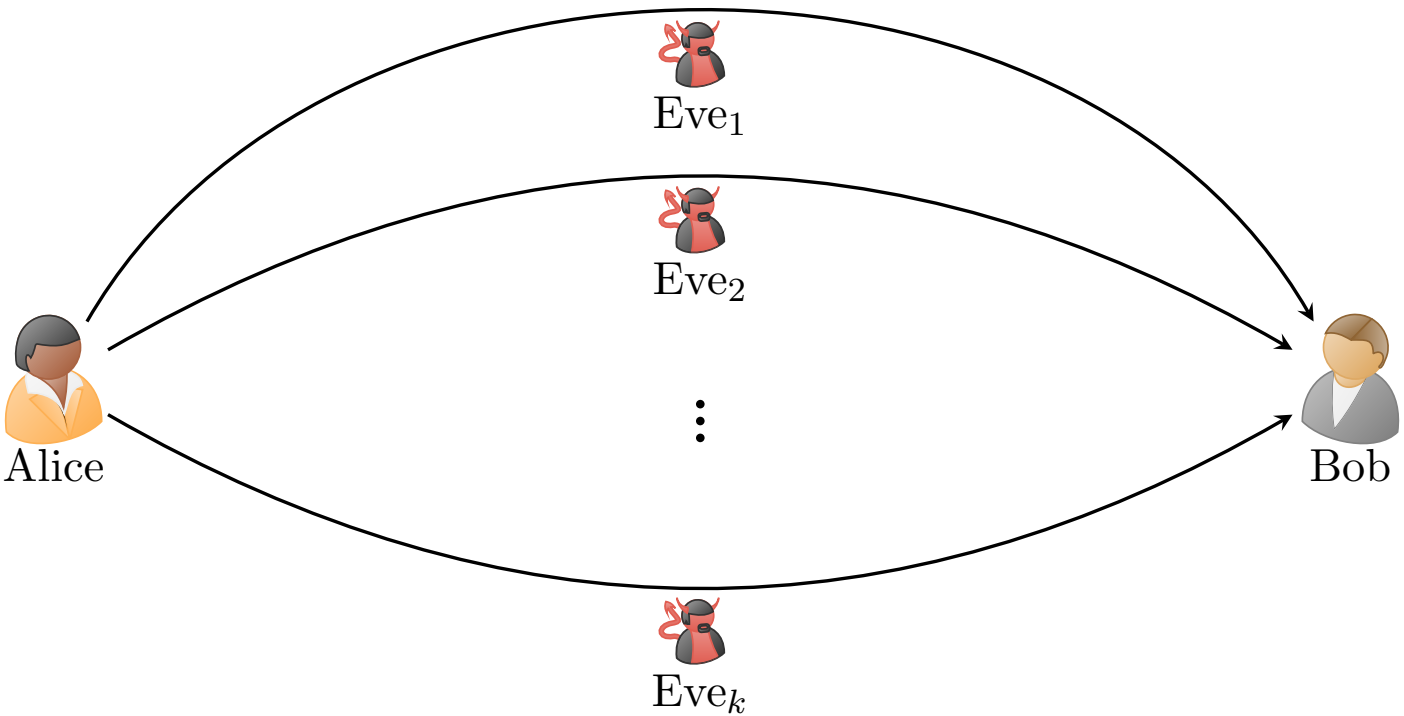

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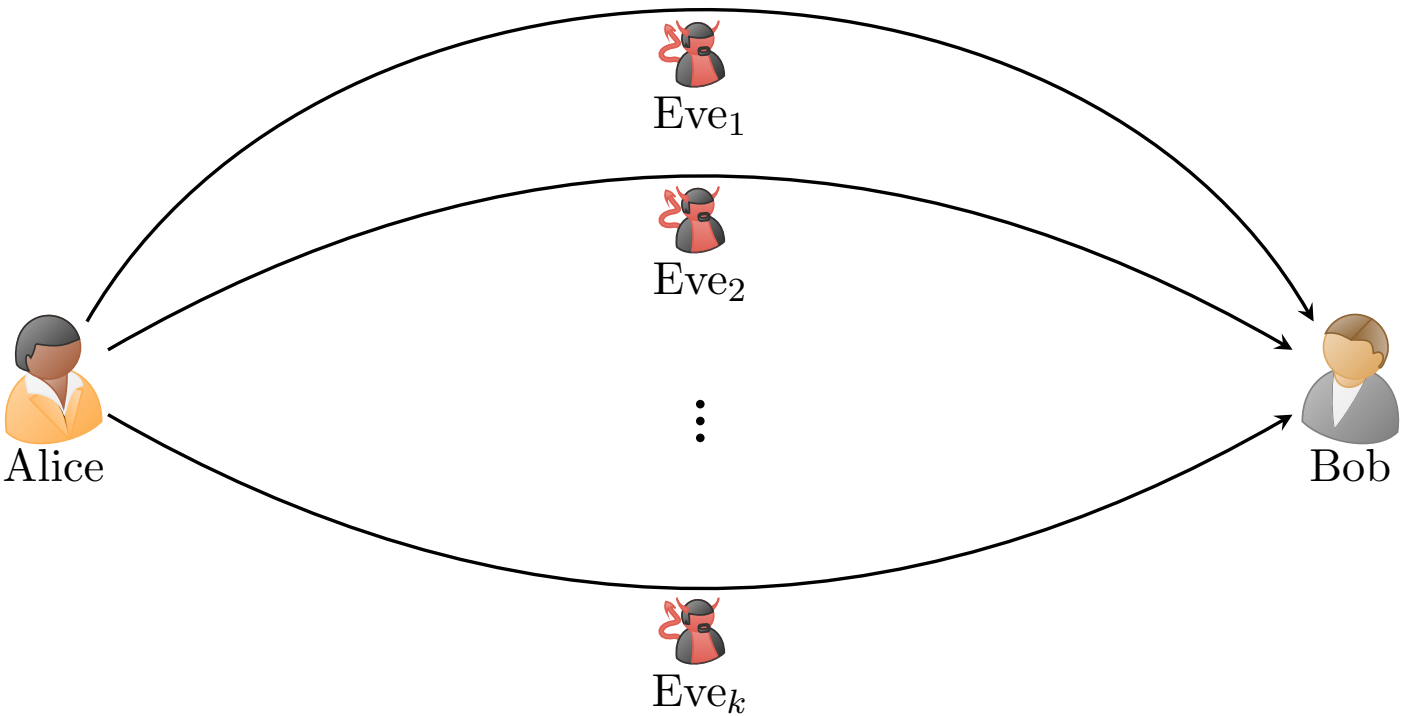

Can we ensure non-malleability information theoretically?

Non-malleable Codes

Suppose we have a coding scheme $(\mathrm{Enc}, \mathrm{Dec})$:

- $\mathrm{Enc}: \{0,1\}^{\ell} \to \{0,1\}^{n}$ (possibly probabilistic)
- $\mathrm{Dec}: \{0,1\}^{n} \to \{0,1\}^{\ell} \cup \{\perp\}$ (deterministic)

$$m \xrightarrow{\mathrm{Enc}} c \xrightarrow{\mathrm{Dec}} m$$

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$$m \xrightarrow{\text{Enc}} c \xrightarrow{\text{Tampering } f} \widetilde{c} \xrightarrow{\text{Dec}} \widetilde{m}$$

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  For example, consider the following tampering function

$$f(c) = \mathrm{Enc}\Big(\mathrm{Dec}(c) + 1\Big)$$

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- Defined w.r.t. some fixed tampering family $\mathcal{F}$

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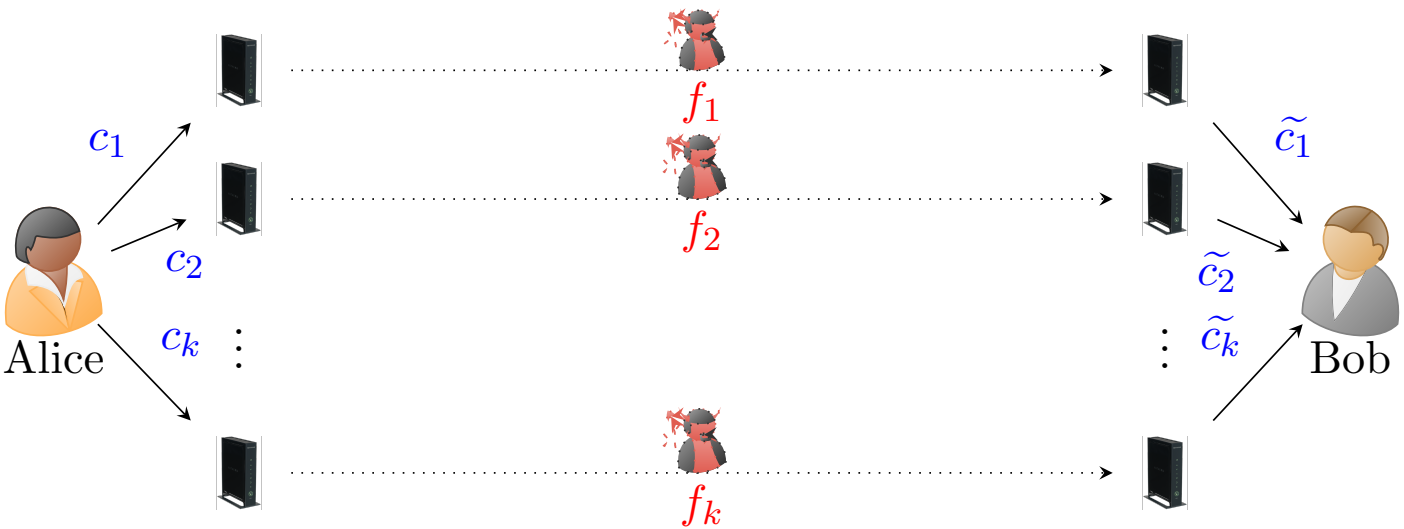
k-Lookahead Tampering model



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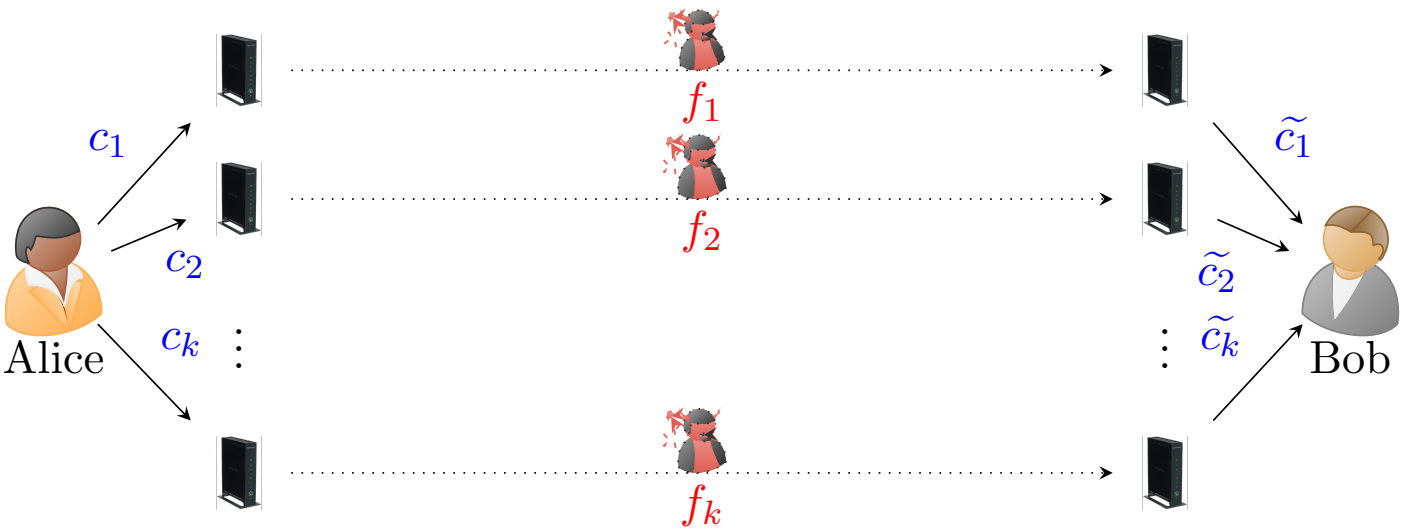

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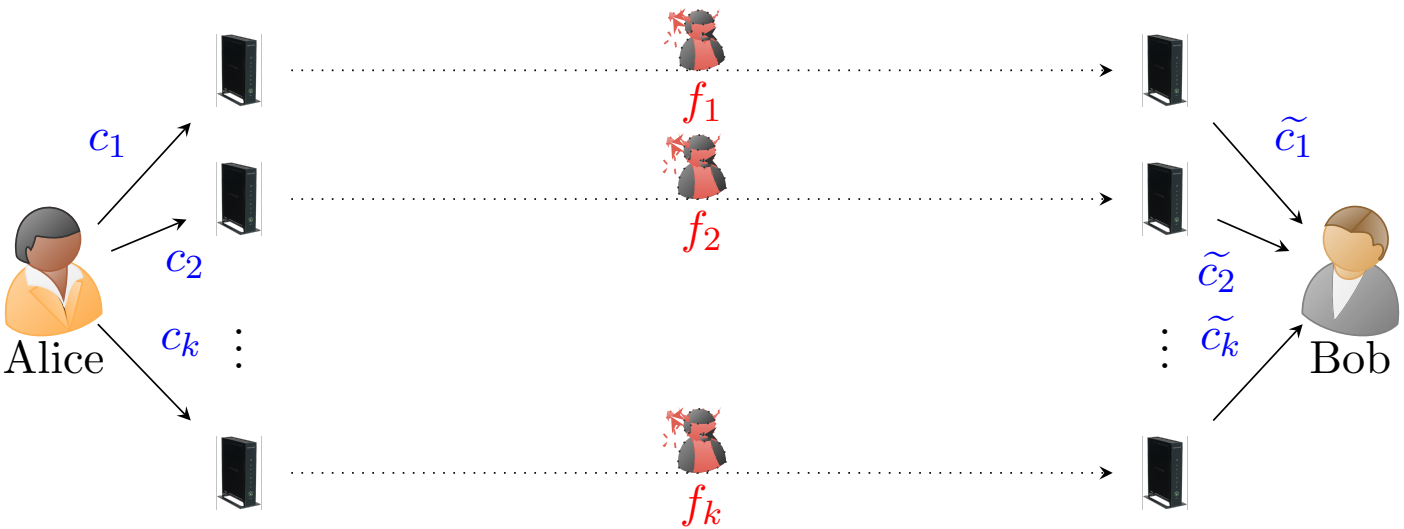

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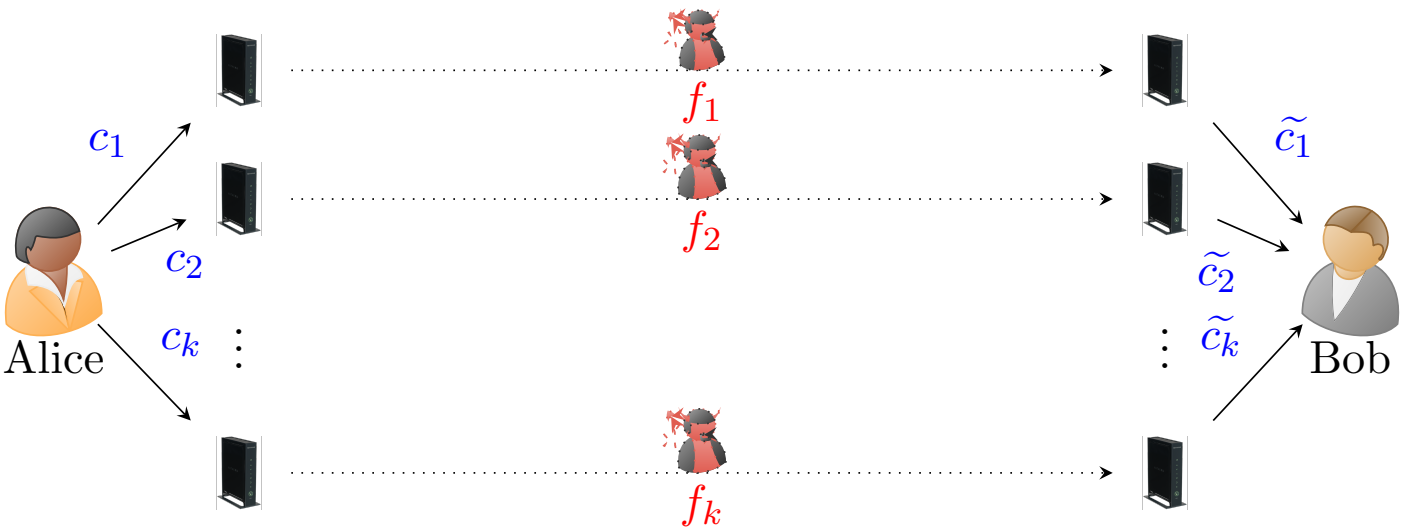

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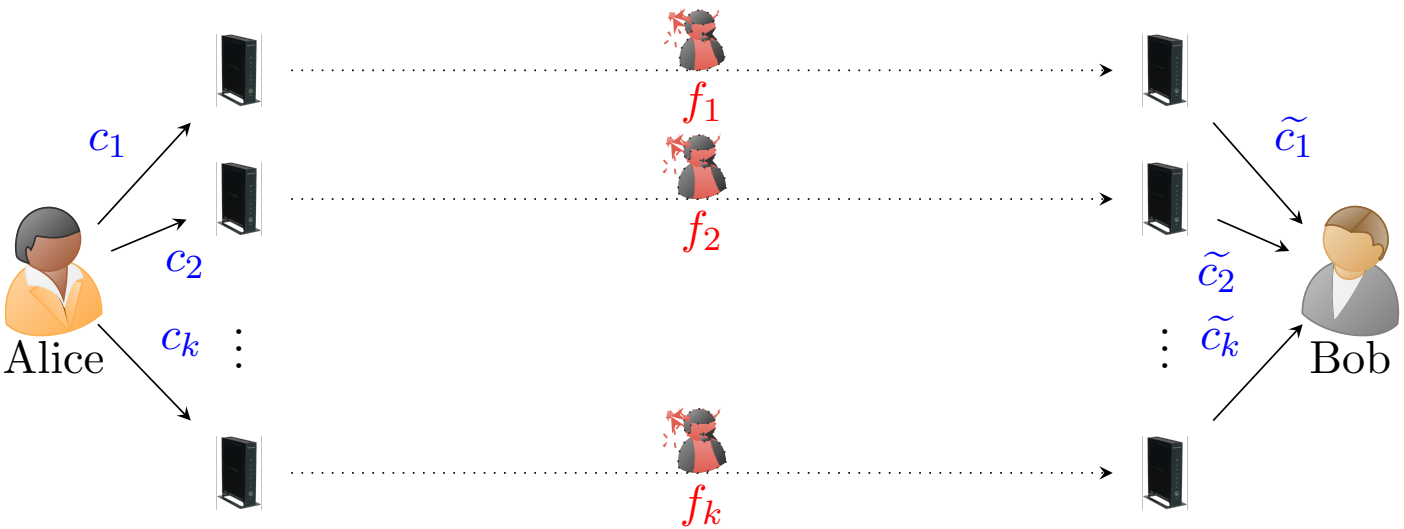

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- If the adversary blocks or slows the information stream, it would outrightly signal his intrusion

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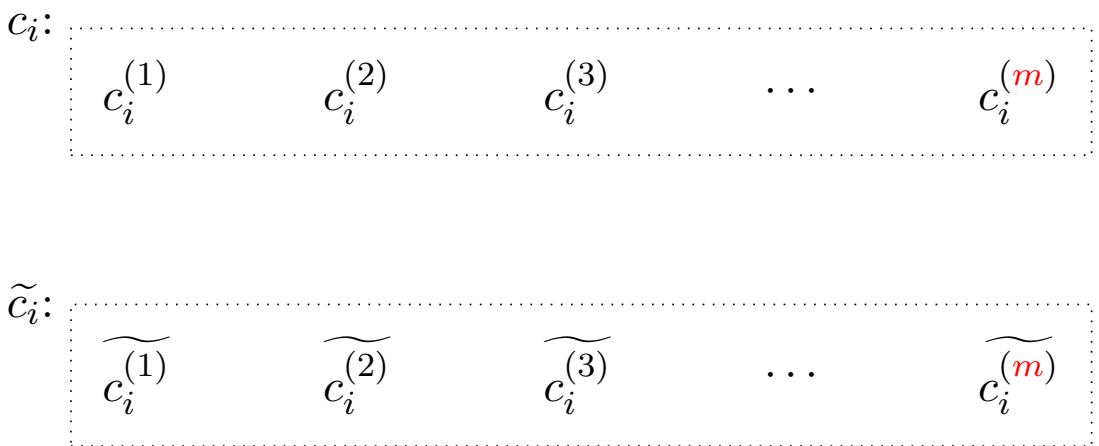

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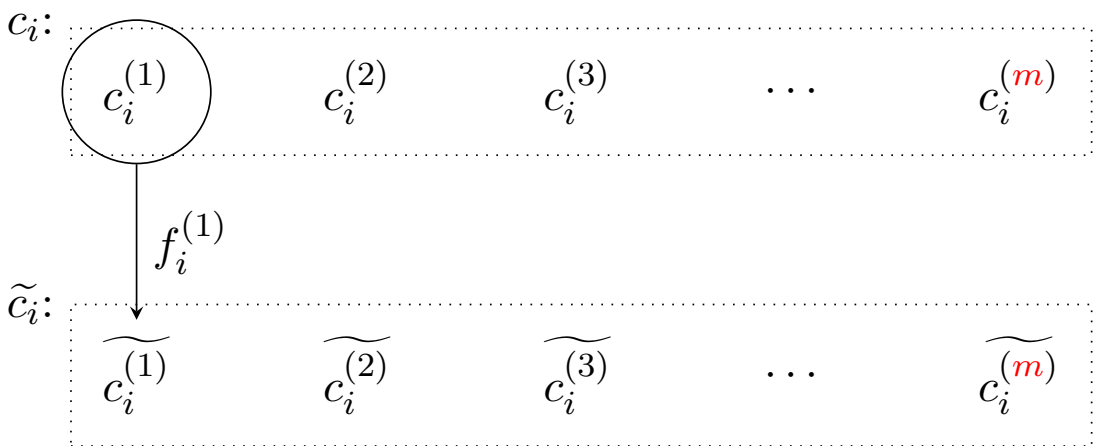

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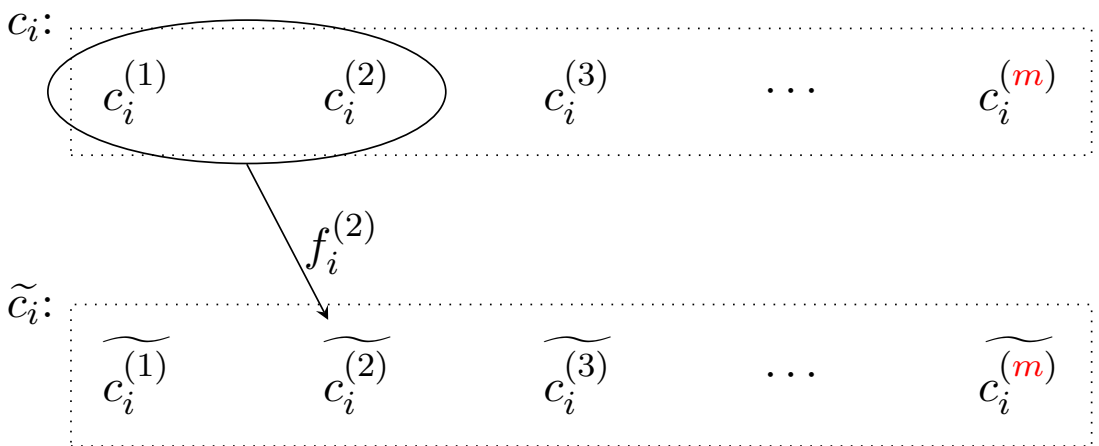

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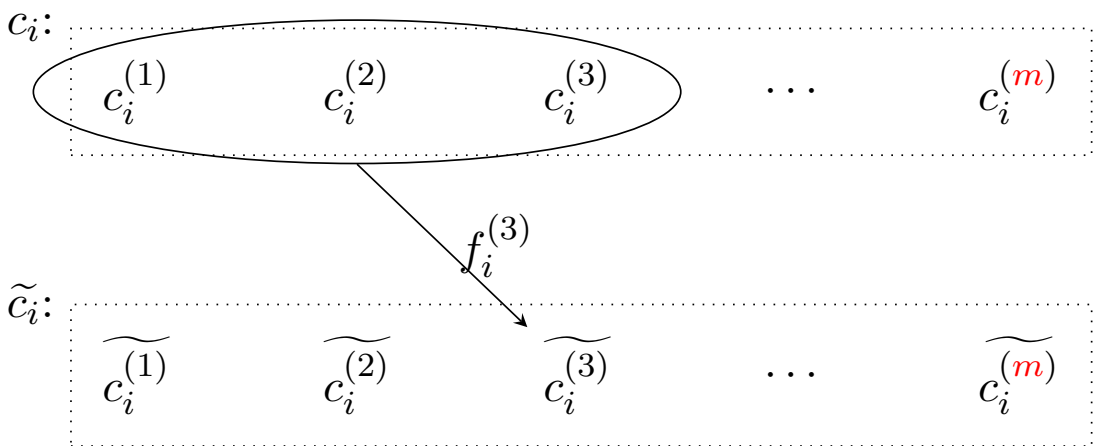

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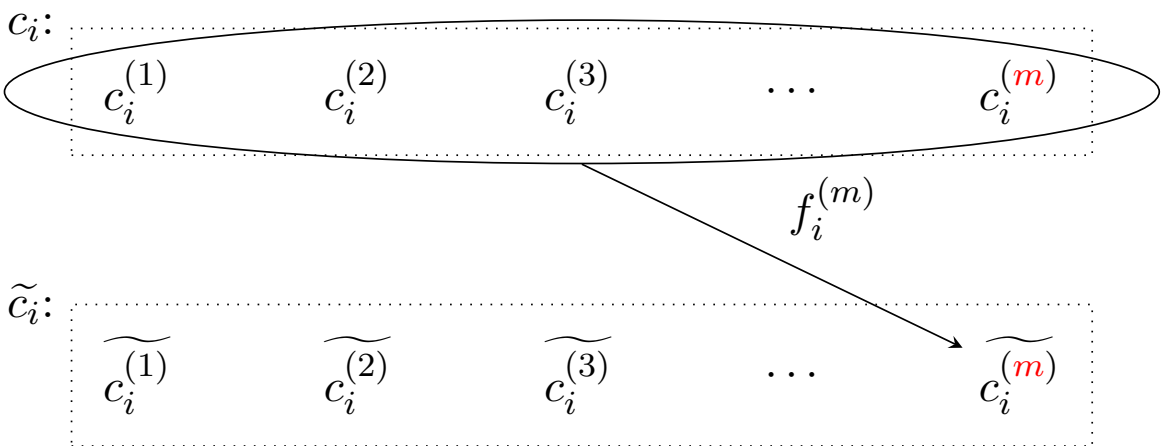

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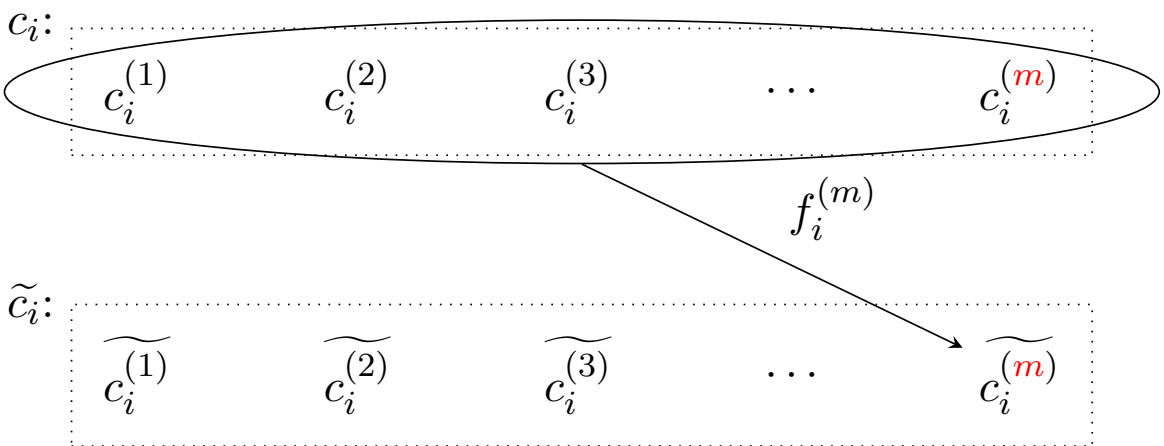

- Strongest: when the number of blocks m equals to 1. This is the widely studied k-split-state tampering
- Weakest: when the number of blocks m equals to the length of c_i, i.e. each bit is a block

Our Contributions

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For k-split-state tampering, Cheraghchi and Guruswami [ITCS-14] showed that the best achievable rate $\ell/n \leqslant 1 - 1/k$

Upper Bound

For k-lookahead, the best achievable rate is $1 - 1/k$

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NMC against 2-lookahead

There exists an efficient non-malleable code, with negligible simulation error, against the 2-lookahead tampering with rate $1/3$

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NMC against 3-split-state

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In an independent and concurrent work, Kanukurthi, Obbattu and Sekar [EUROCRYPT-18] also obtained a rate $1/3$ construction in 3-split-state

Related Works: Split-State

In prior works, the construction of k-lookahead NMC coincided with k-split-state NMC

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k	Work	Best Rate
10	Chattopadhyay and Zuckerman [FOCS-14]	(small) const.
4	Kanukurthi, Obbattu and Sekar [TCC-17]	1/3
3	This work Kanukurthi, Obbattu and Sekar [EUROCRYPT-18]	1/3
2	Dziembowski, Kazana and Obremski [CRYPTO-13] Aggarwal, Dodis and Lovett [STOC-14] Aggarwal, Dodis, Kazana and Obremski [STOC-15] Li [STOC-17]	$1/\log n$

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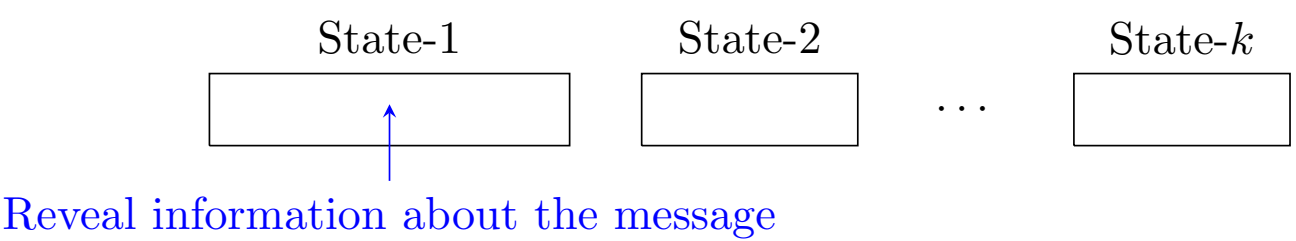

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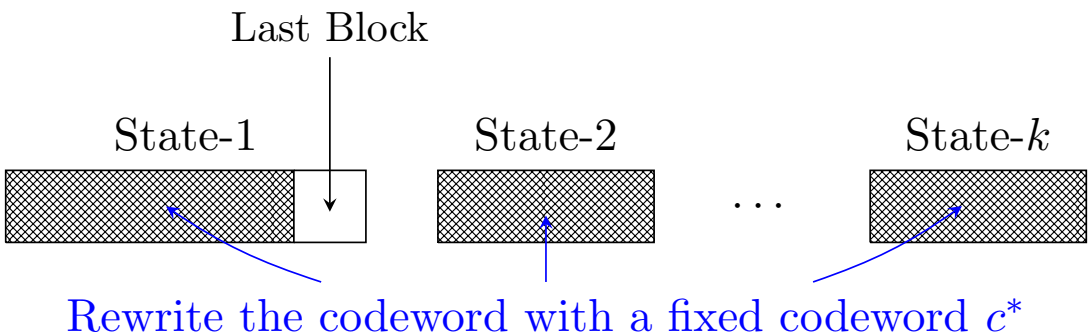

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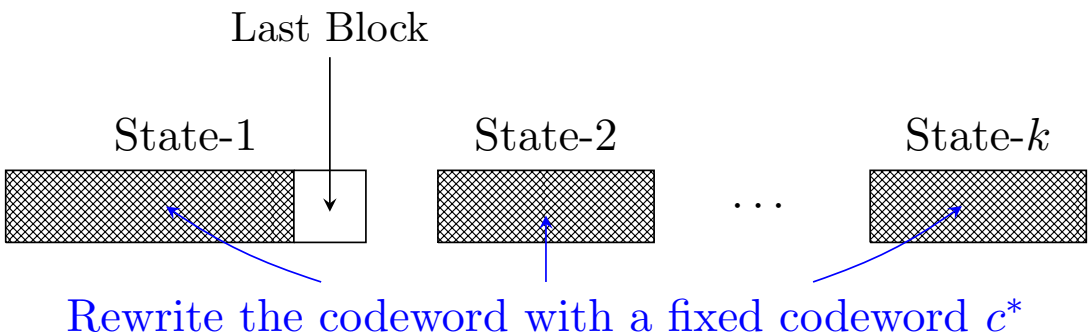

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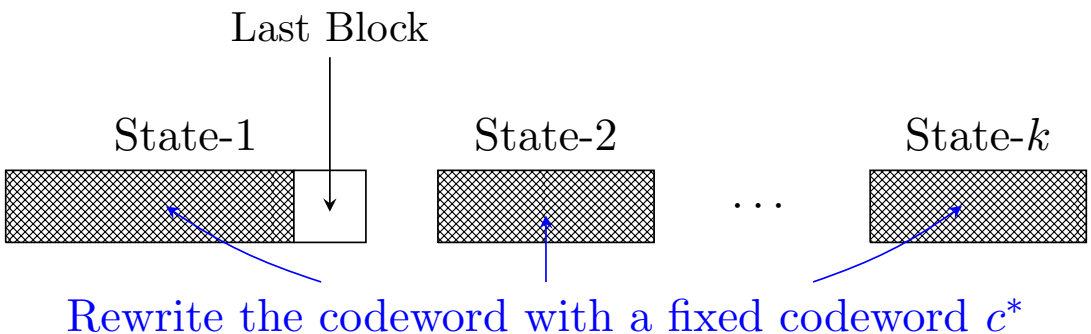

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- At the last block, we invoke the distinguisher $\mathcal{D}$. Depending on the distinguisher output, we either fill in the last block of c^* or make the codeword invalid
- The probability of

$$\Pr\left[\mathrm{Tamper}_f^{m_0} = m^*\right] \quad \text{and} \quad \Pr\left[\mathrm{Tamper}_f^{m_1} = m^*\right]$$

will be significantly different

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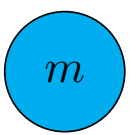
- Kanukurthi, Obbattu and Sekar [TCC-17]'s construction of four-state NMC is the starting point of our construction

Construction of Kanukurthi, Obbattu and Sekar [TCC-17]



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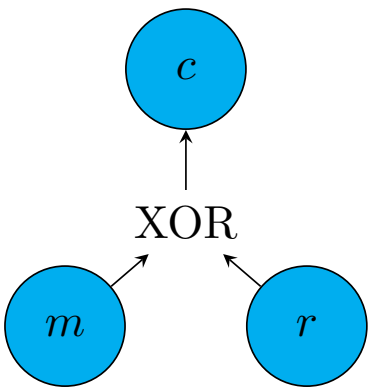

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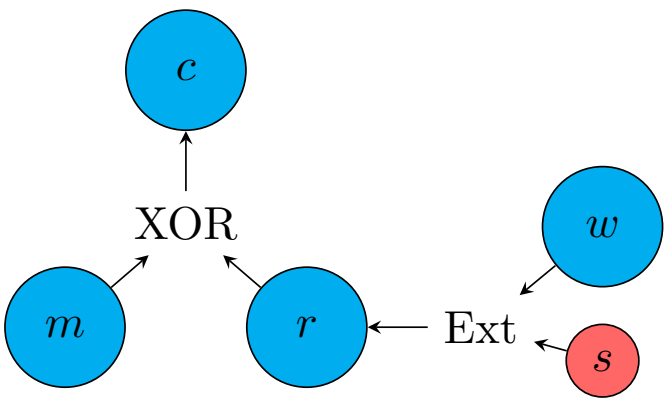

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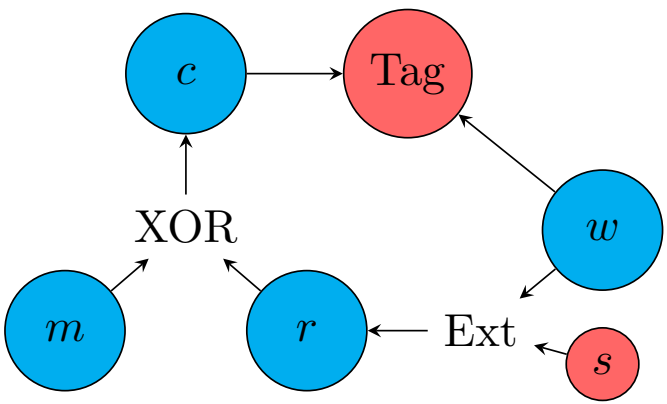

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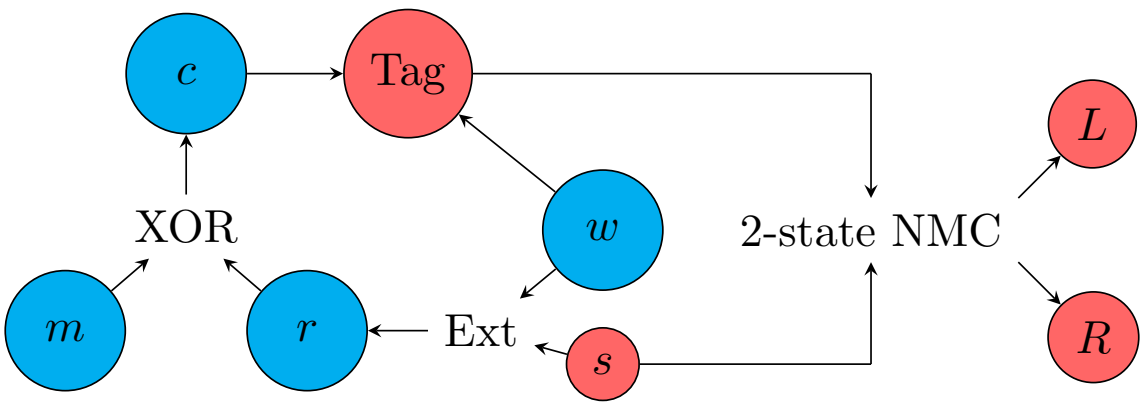

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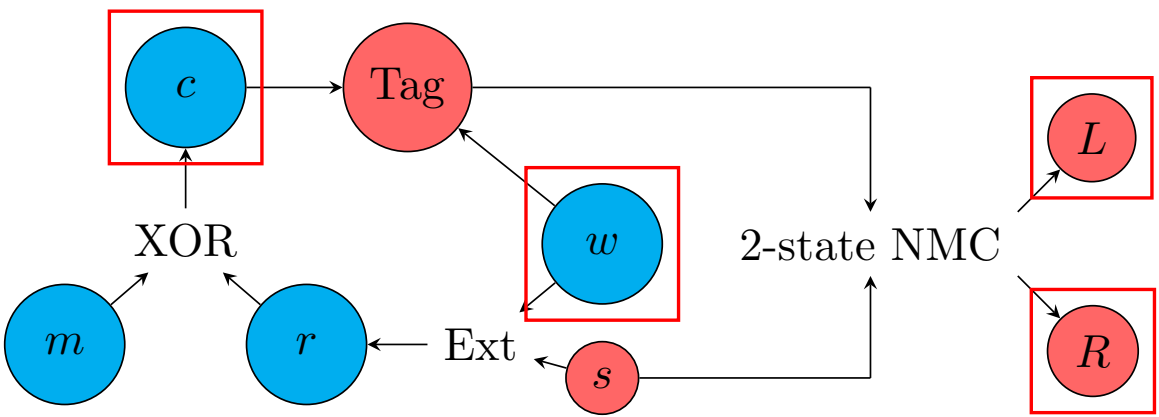
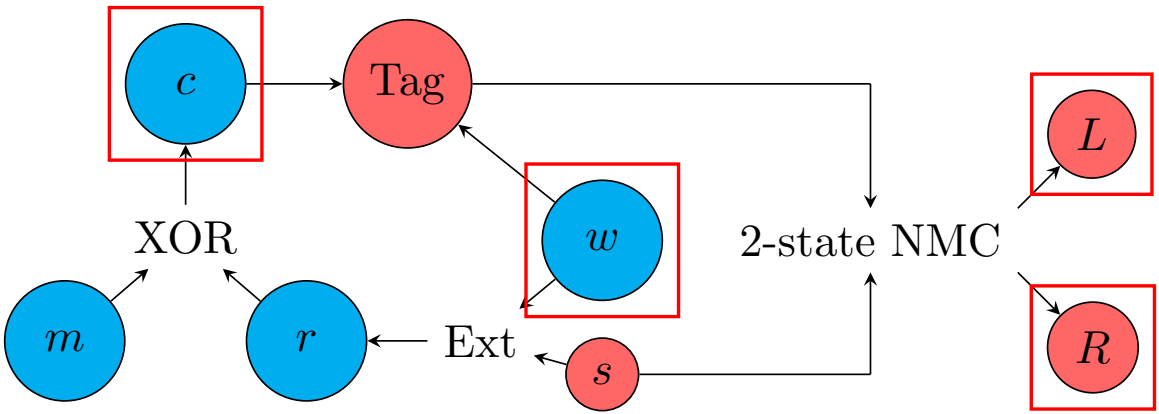


Our Modification



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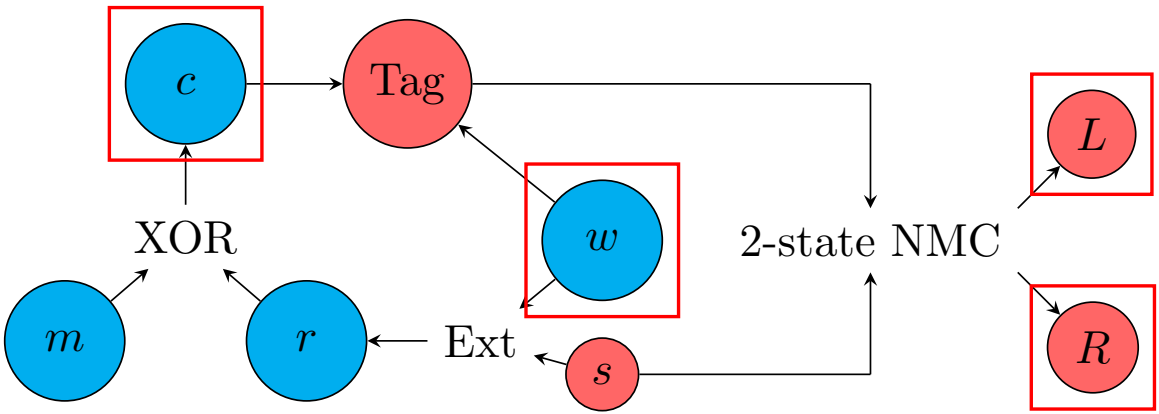

- Now, instead of storing c, w, L, R individually, we are going to merge some states and store it as $\underrightarrow{(w, R)}$ and $\underrightarrow{(L, c)}$

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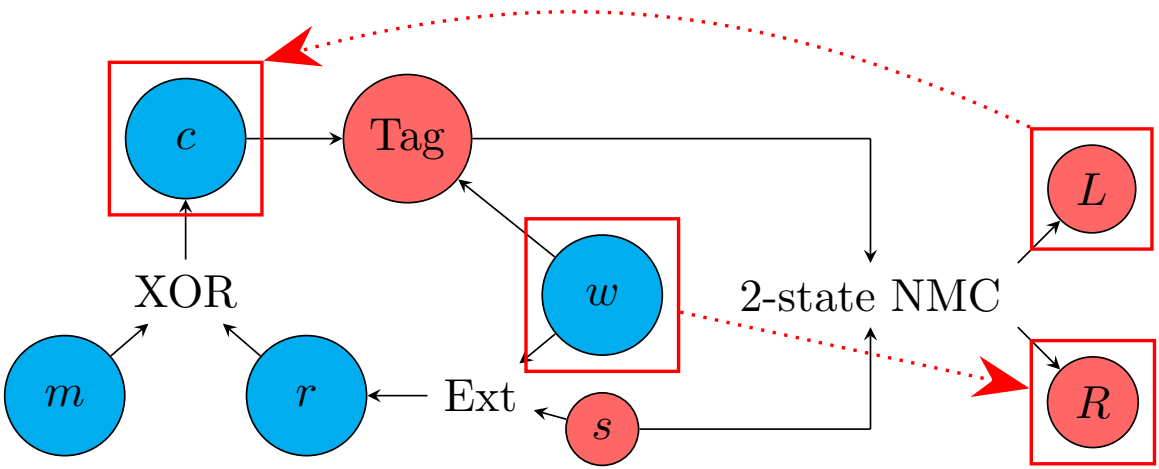

- Now, instead of storing c, w, L, R individually, we are going to merge some states and store it as $\underrightarrow{(w, R)}$ and $\underrightarrow{(L, c)}$
- This results in two issues:
  - The tampering on R now depends on w
  - The tampering on c now depends on L

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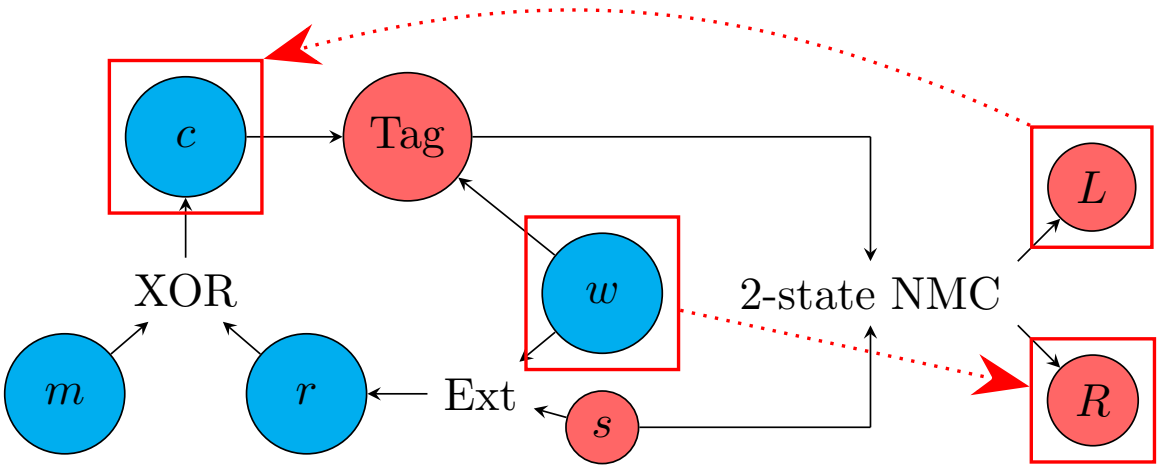

- Our codeword: $\underrightarrow{(w, R)}$ and $\underrightarrow{(L, c)}$

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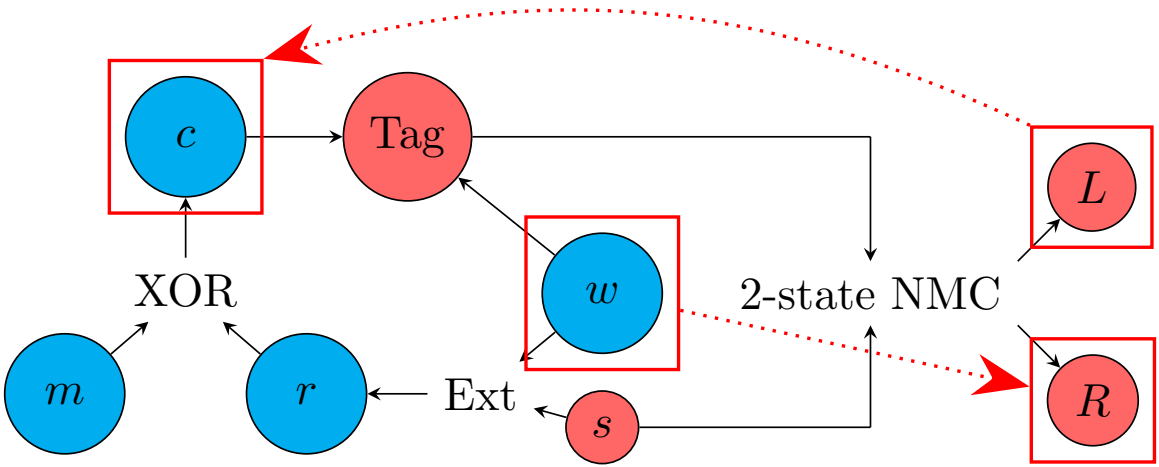

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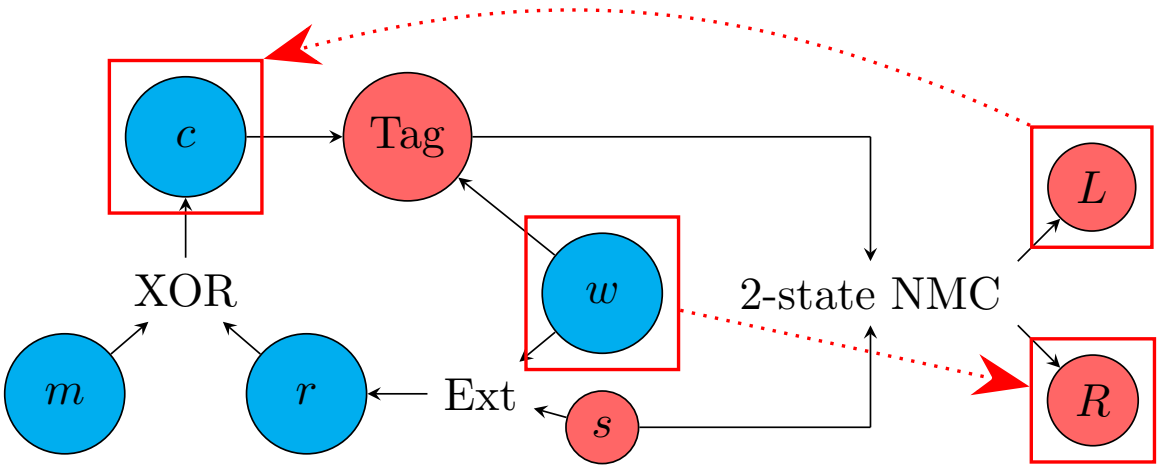

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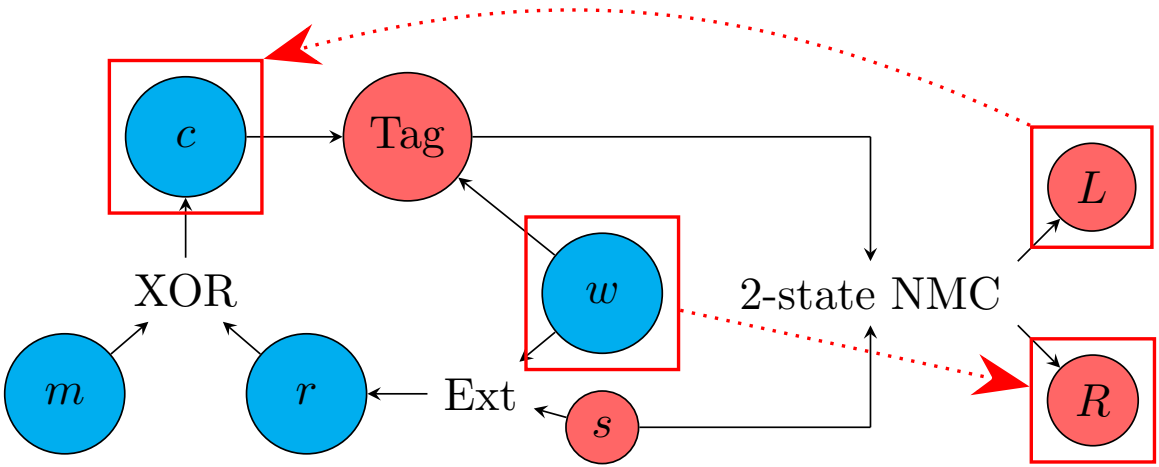

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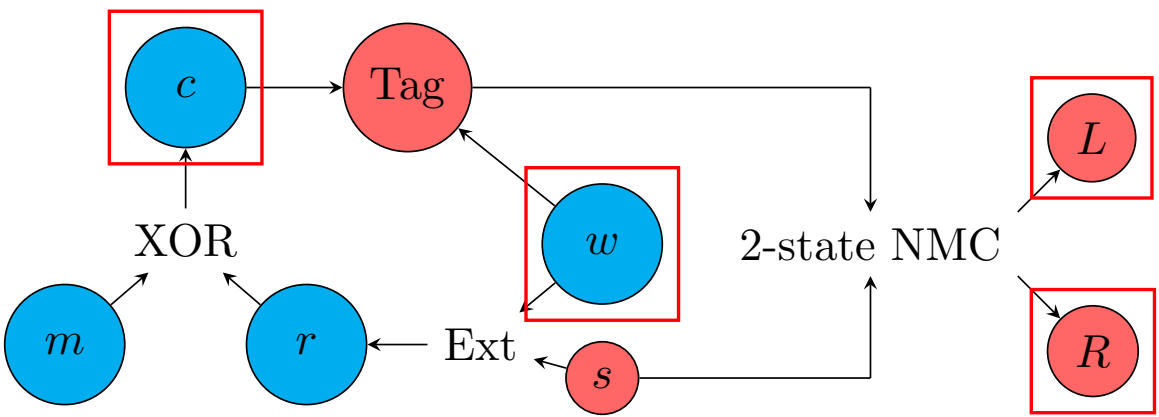
- We use an additional property of Aggarwal, Dodis and Lovett [STOC-14]'s construction, called *augmented non-malleability* (identified by Aggarwal et al. [AAG+16]). At an intuitive level, this property allows us the freedom to simulate the left state L and, hence, simulate the tampering on c

3-state NMC

NMC against 3-split-state

There exists an efficient non-malleable code, with negligible simulation error, against the 3-split-state tampering with rate 1/3



3-state NMC

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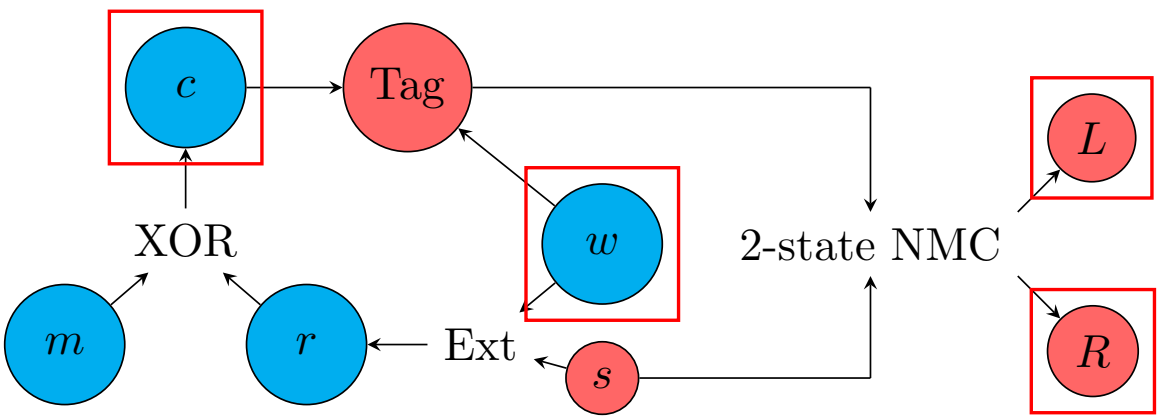

- Our 3-state codeword: c, $\underbrace{(L, w)}$ and R

3-state NMC

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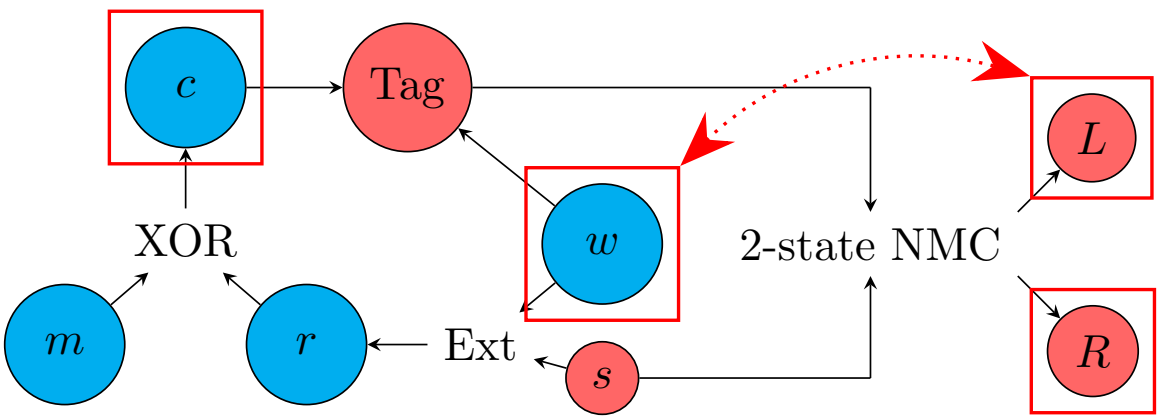

- Our 3-state codeword: c, $\underbrace{(L, w)}$ and R
- Tampering on L and w depends on each other
- Resolved similarly as 2-lookahead proof

Summary of Our Results

- For k-lookahead, the best achievable rate $1 - 1/k$
- There exists an efficient non-malleable code, with negligible simulation error, against the 2-lookahead tampering with rate $1/3$
- There exists an efficient non-malleable code, with negligible simulation error, against the 3-split-state tampering with rate $1/3$

Thanks!