Semantic Security versus Active Adversaries

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Joint work with Paul Cuff and Haim Permuter

Ben Gurion University

Information Theory and Applications Workshop

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Motivation

Information Theoretic Security over Noisy Channels

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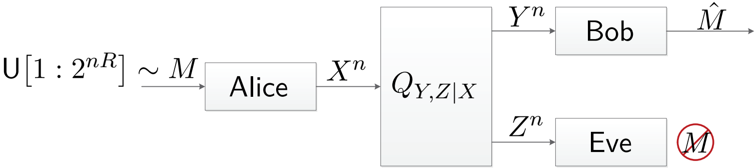
Our Goal: Stronger metrics and remove "known channel" assumption.

Wiretap Channels - Security Metrics

Wiretap Channels and Security Metrics

Degraded [Wyner 1975], General [Csiszár-Körner 1978]



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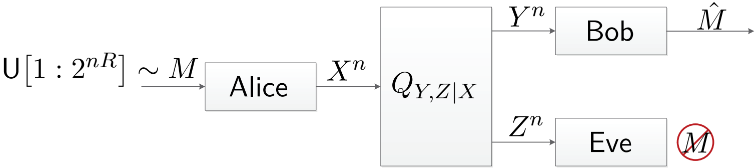
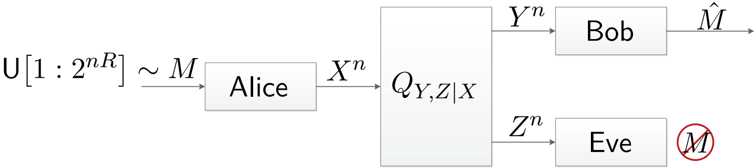


$\{\mathcal{C}_n\}_{n\in\mathbb{N}}$ - a sequence of (n,R)-codes



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- **Weak Secrecy:** $\frac{1}{n}I_{\mathcal{C}_n}(M;Z^n) \xrightarrow[n\to\infty]{} 0.$

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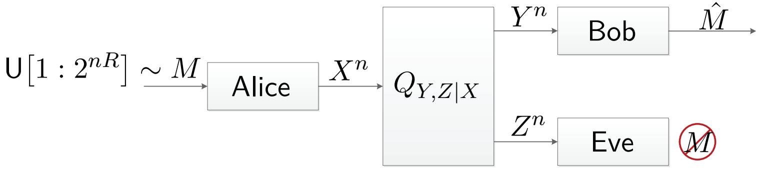

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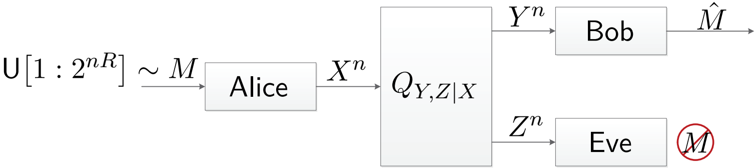

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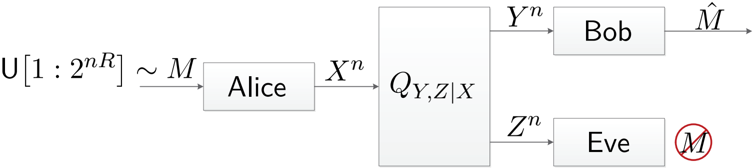

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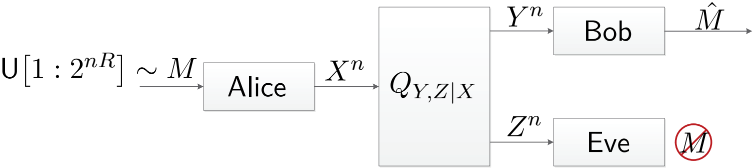

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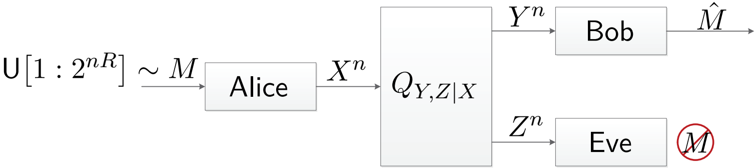

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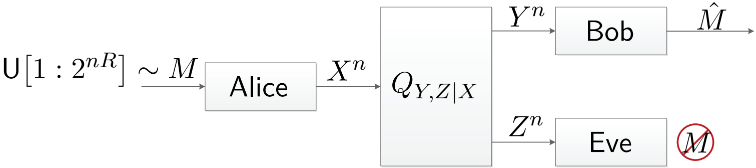

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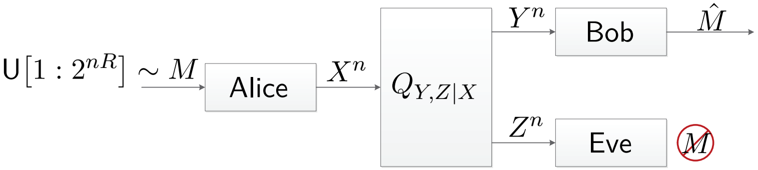

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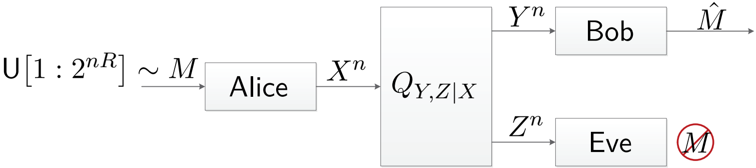

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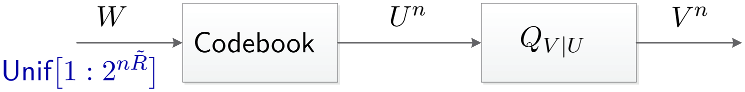
★ A single code must work well for all message PMFs ★

Strong Soft-Covering Lemmas

Soft-Covering - Setup



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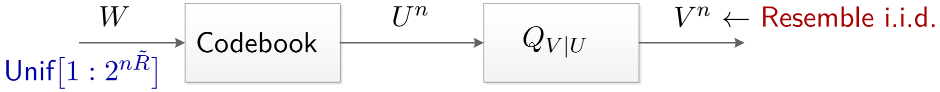

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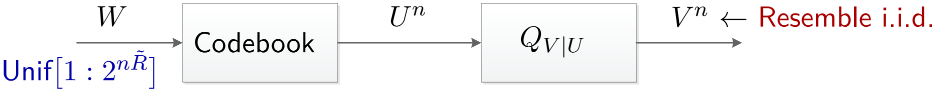

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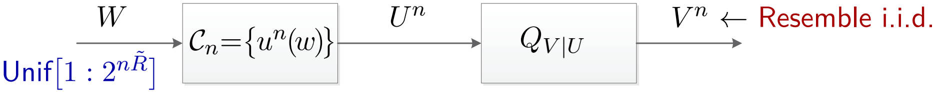

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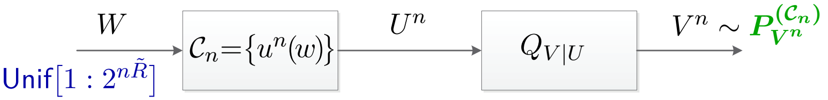

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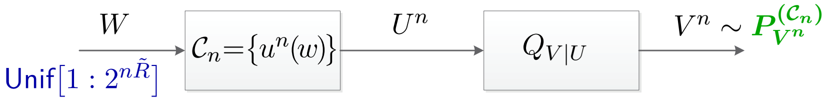

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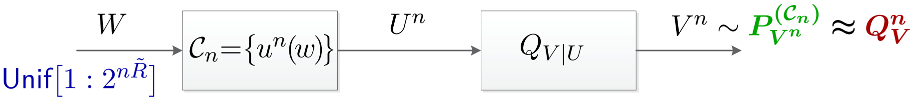

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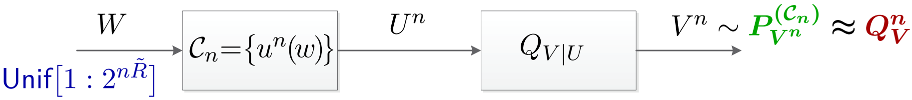

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⋆ **Goal:** Choose $\tilde{R}$ (codebook size) s.t. $P_{V^n}^{(\mathcal{C}_n)} \approx Q_V^n$ ⋆

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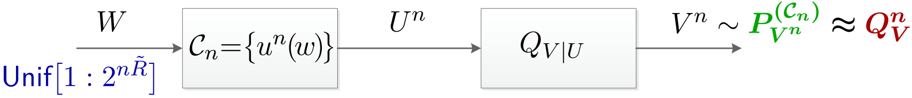

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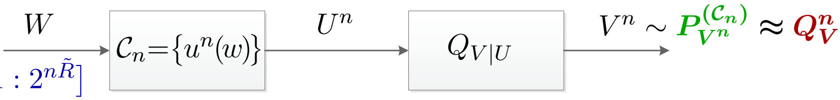

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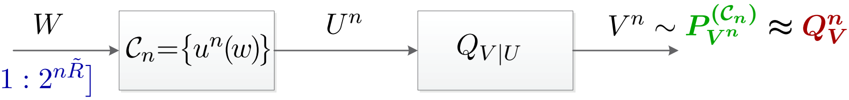

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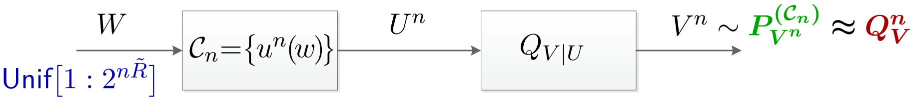

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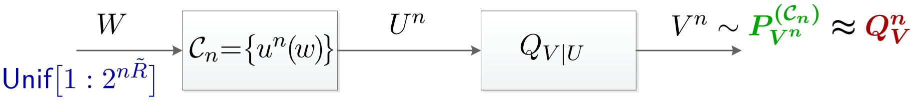

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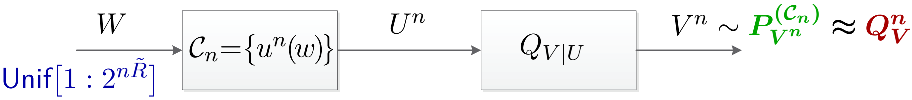
Strong Soft-Covering Lemma



Lemma (ZG-Cuff-Permuter 2016)

If $\tilde{R} > I_Q(U;V)$, *then there exist* $\gamma_1, \gamma_2 > 0$ *s.t. for* n *large enough*

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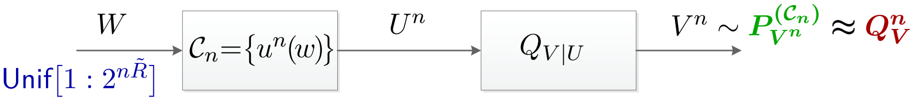

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$$\underset{\text{Unif}\left[1\,:\,2^{n\tilde{R}}\right]}{\xrightarrow{\;W\;}} \boxed{\mathcal{C}_n=\{u^n(w)\}} \xrightarrow{\;U^n\;} \boxed{Q_{V|U}} \xrightarrow{\;V^n \sim P_{V^n}^{(\mathcal{C}_n)} \approx Q_V^n\;}$$

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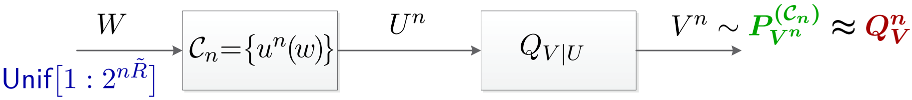

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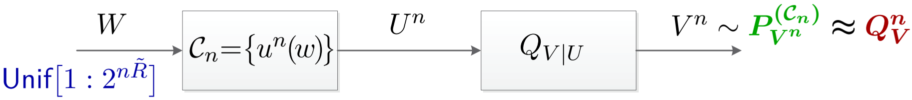

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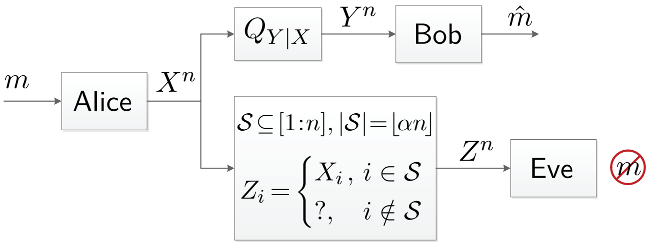
- **Satisfy exponentially many security constraints:**
  - Semantic security.
  - Eavesdropper's channel uncertainty & active adversaries.
- **Extensions:** Heterogeneous version, superposition codes.

Some Applications

Wiretap Channels of Type II - Definition

[Ozarow-Wyner 1984]



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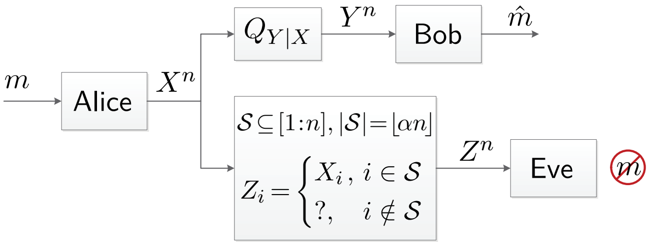

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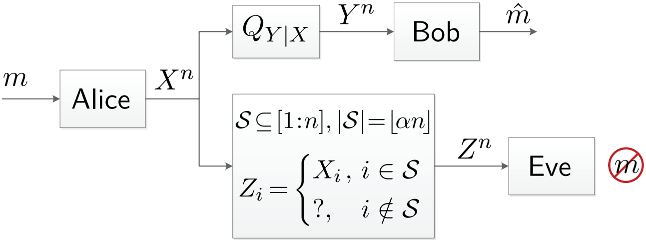

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0	0	1	0	1	1	1	0	1	0

$n = 10$ $\boldsymbol{\alpha = 0.6}$

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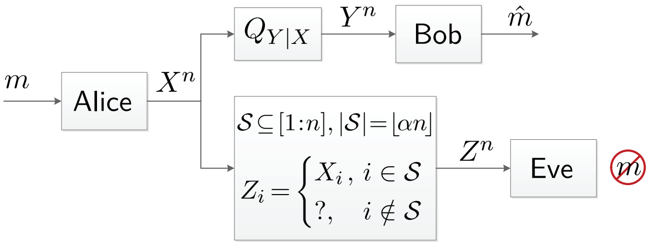

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Transmitted:	0	0	1	0	1	1	1	0	1	0
Observed:	?	0	?	?	1	1	1	?	1	0

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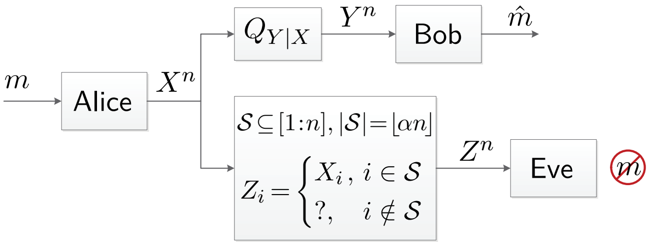

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Observed:	?	0	?	?	1	1	1	?	1	0

$n=10$ $\boldsymbol{\alpha=0.6}$

⋆ Ensure security versus all possible choices of observations ⋆

Wiretap Channels of Type II - Past Results

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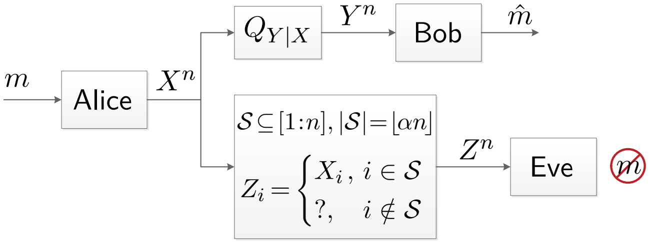

- **Ozarow-Wyner 1984:** Noiseless main channel

Wiretap Channels of Type II - Past Results

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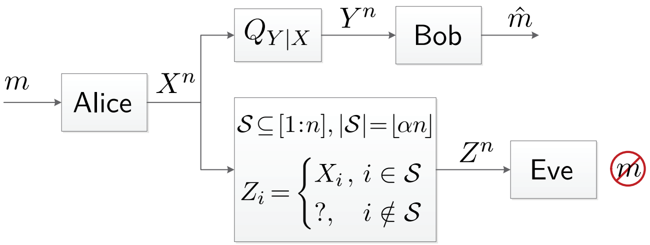

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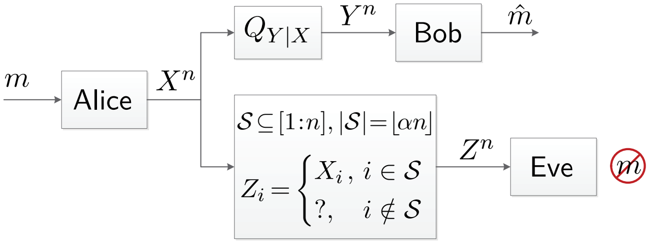

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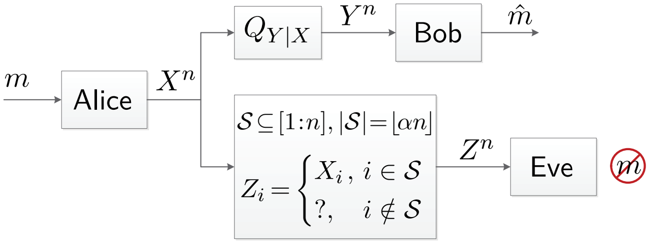

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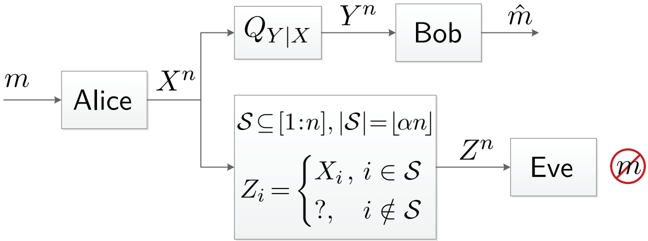

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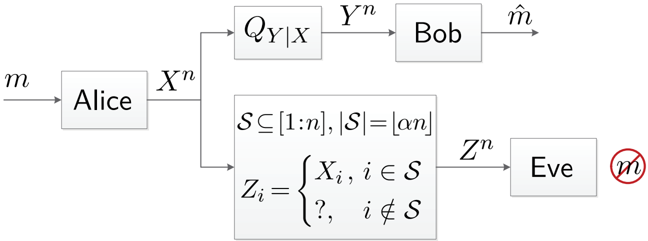

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  - Lower & upper bounds - Not match in general.

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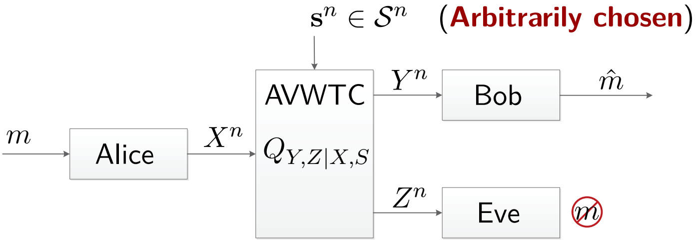
- Standard (erasure) wiretap code & Stronger tools for analysis.

A Generalization - Arbitrarily Varying WTCs



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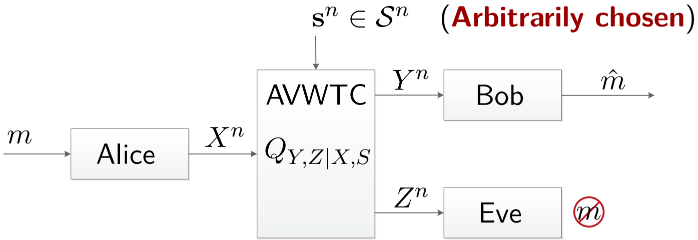

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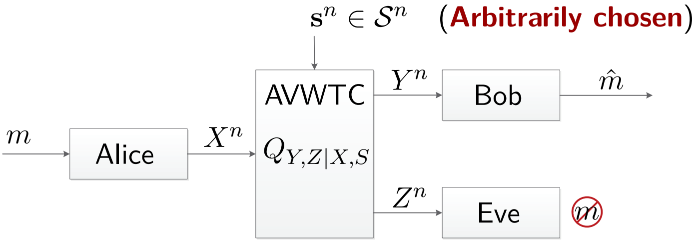

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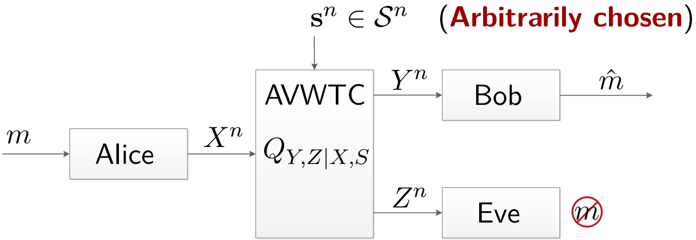

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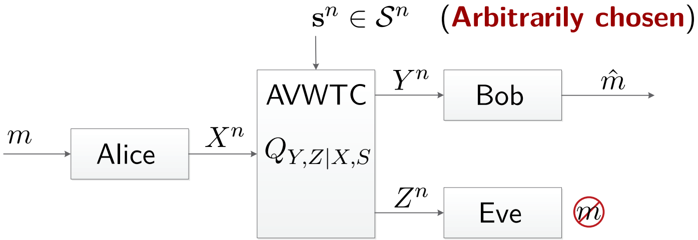

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★ **Subsumes WTC II model and result** ★

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Thank you!