Mixing Email with BABEL'96

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Introduction

- The most critical network building block for anonymity: Mix by Chaum'81
- Absolute anonymity: dining cryptographers algorithm and protocol by Chaum'88
  - Impractical due to the large protocol overhead
  - Hard to provide secure pairwise channels and a synchronized broadcast channel
- Advancement being sought

Related work

- Anonymous Email systems
  - Penet: Finland 1990s
  - Cypherpunk: 1990s – now?
  - Mixmaster: 1990s – now?
  - Implementations of the concept of Mix by a single individual or a group of contributors
- Systematic improvements needed

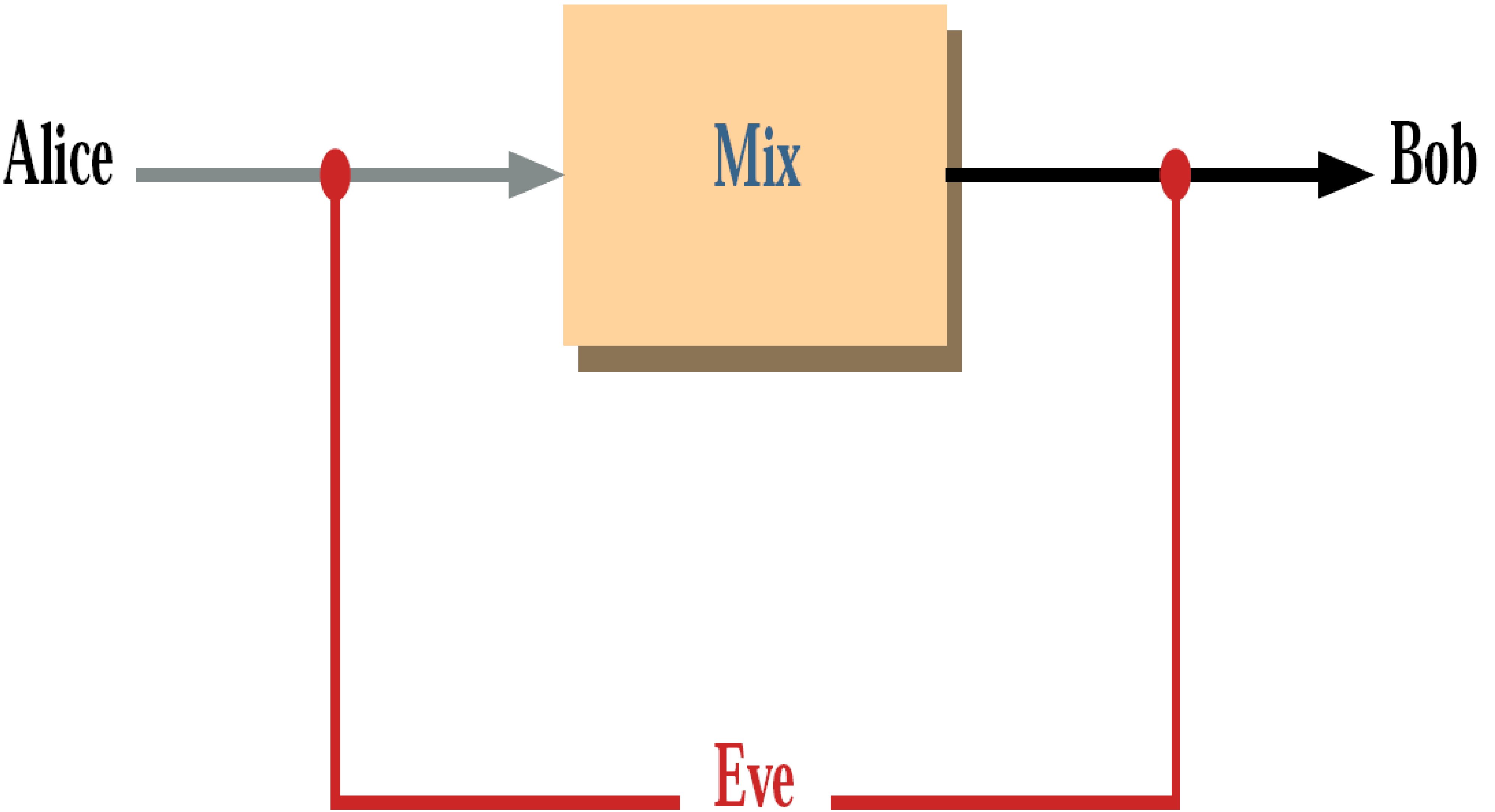
Desired properties (requirements)

- Email systems accommodate anonymity
- Hard to determine the sender
- Recipient can reply the anonymous sender
- End-point anonymity preserved, intermediate mixes are not maximally trusted
- Infrastructure resistant to active attacks
- Sender gets an anonymous confirmation
- Low noise

Notation

M	message; sequence of ASCII bits
$E_x(M)$	encryption of M with X's public key
$D_x(M)$	decryption of M with X's private key
$K\{M\}$	conventional encryption of M with key K
(M_1, M_2)	concatenation of M_1 and M_2
$\mathcal{A}_x$	X's email address.
$\lceil M \rceil^{\Omega}$	padding string M to length Ω (by appending random bits)
$\lfloor M \rfloor^{\Omega}$	trimming string M to length Ω (by removing trailing bits)

Mix, revisted



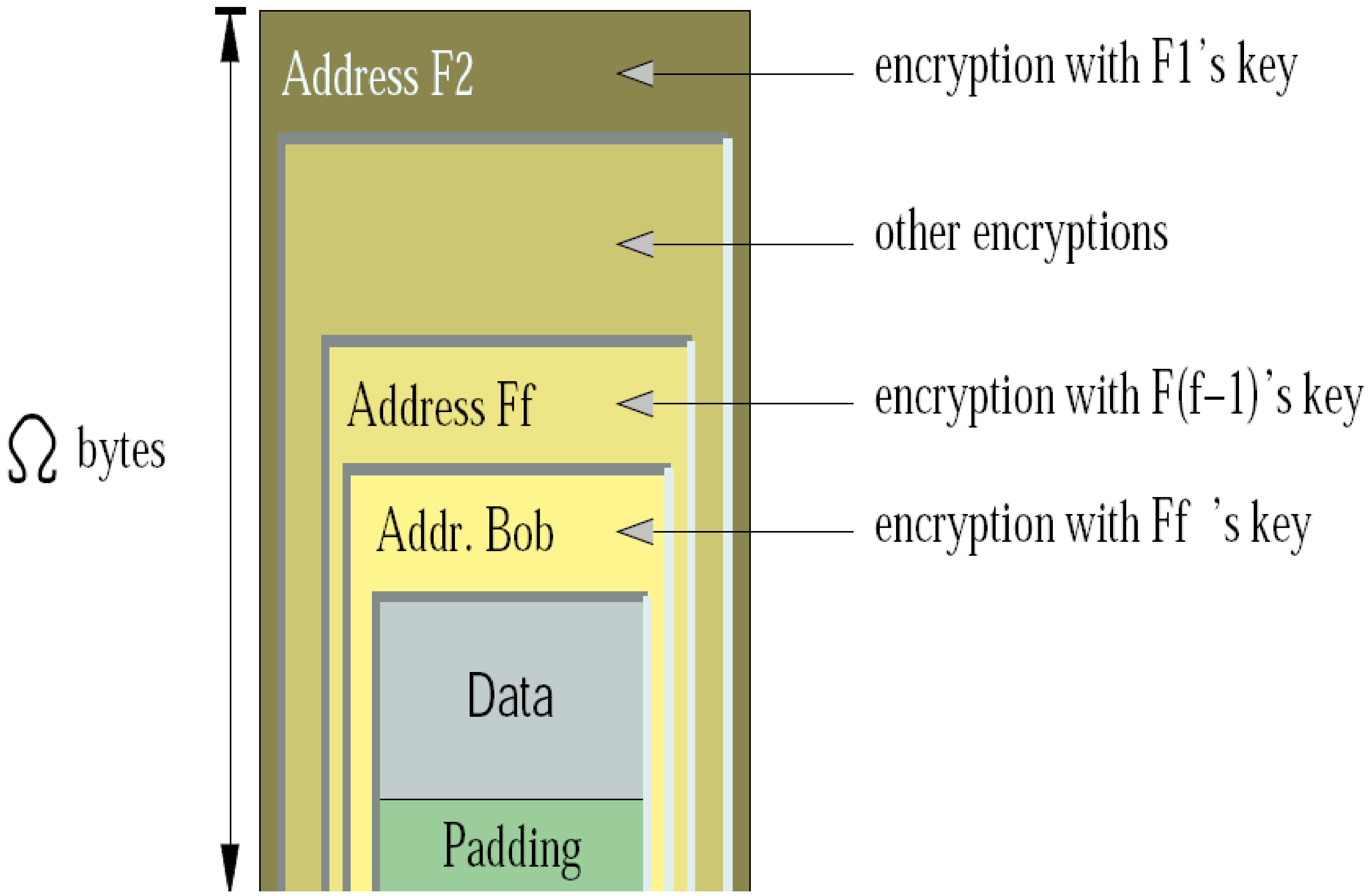
Attacks

- Passive
  - Content correlation:
    - uniform length, padding, nonce
  - Time correlation:
    - Regular vs. interval batching
- Active
  - Isolate and Identify
  - Message replay:
    - time stamp, message identifier
  - Cascading or chaining mixes

BABEL

- Forward path
  - Composition by sender
  - Processing by mixes
  - What does a mix know?

Forward message



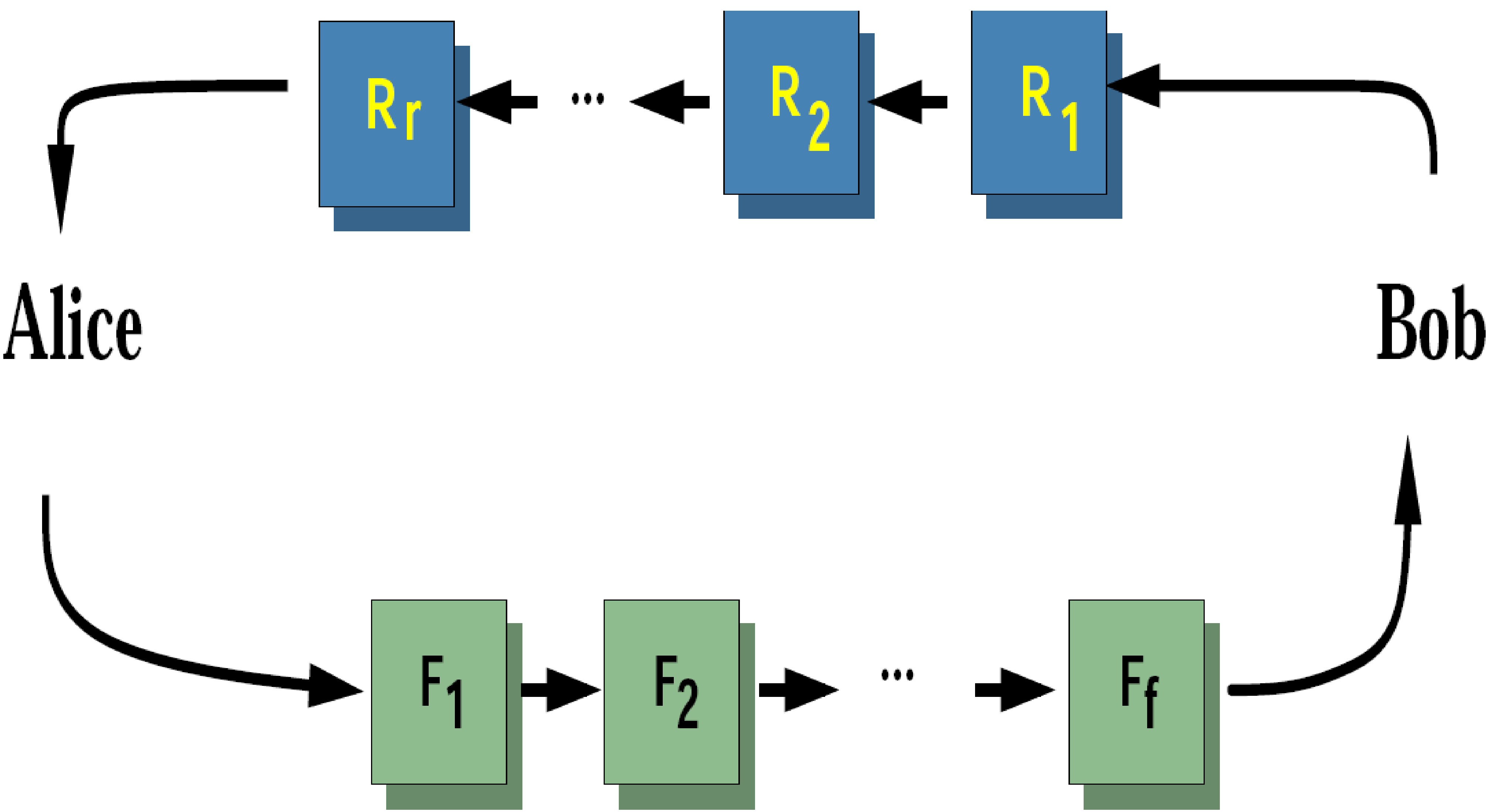
Forward message

$$x_f =$$
$$E_{F_1}(\mathcal{A}_{F_2}, E_{F_2}(\ldots E_{F_{f-1}}(\mathcal{A}_{F_f}, E_{F_f}(\mathcal{A}_{\mathrm{Bob}}, \lceil M \rceil^{\Omega})) \ldots))$$

BABEL

- Return path
  - Creating RPI
  - Replying by recipient
  - Reply processing by BABEL
  - Handling replies at the originator
  - Two-way anonymous conversation
  - Security of replies
  - Inter-mix Detours
  - Indirect replies

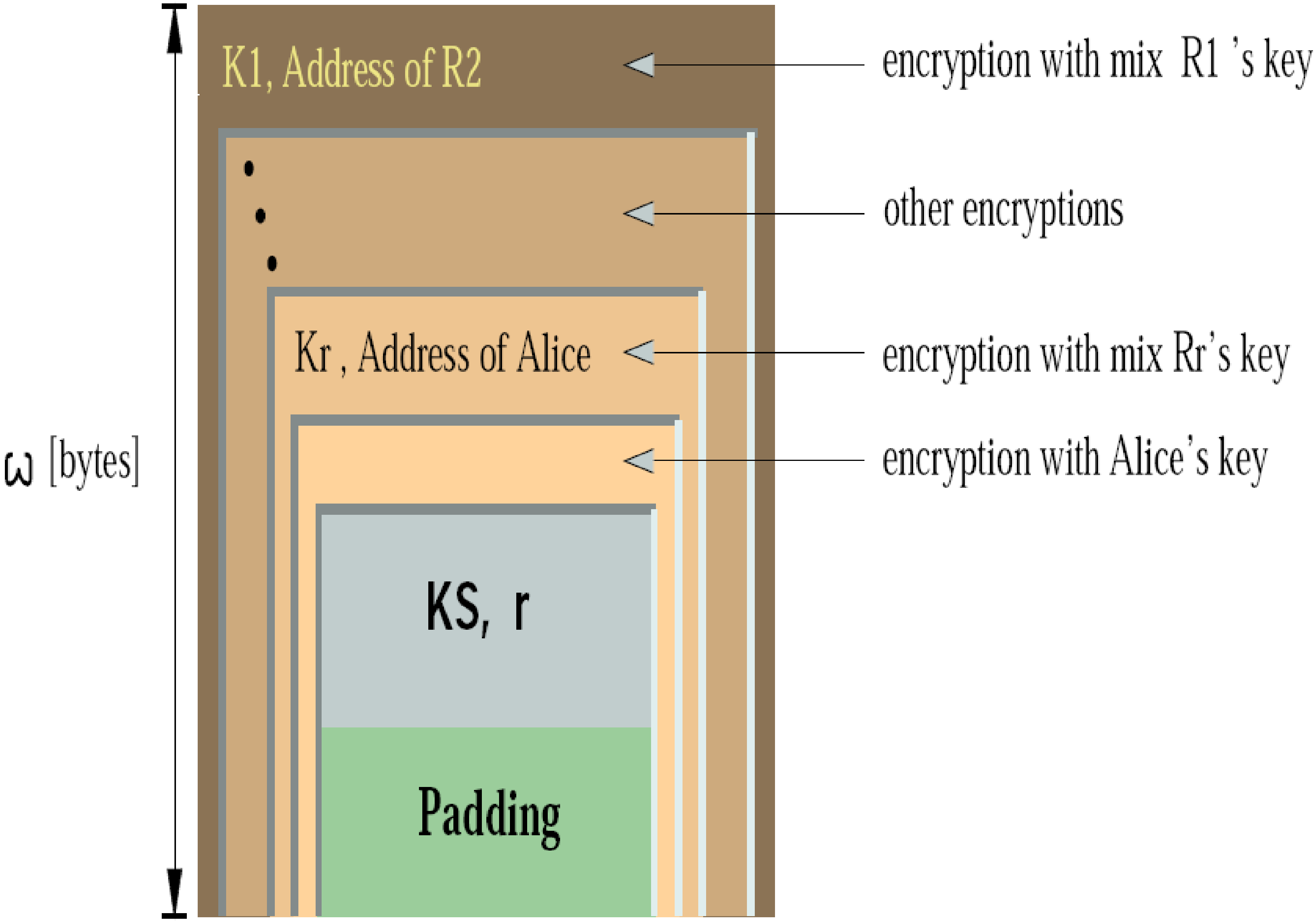
Return path



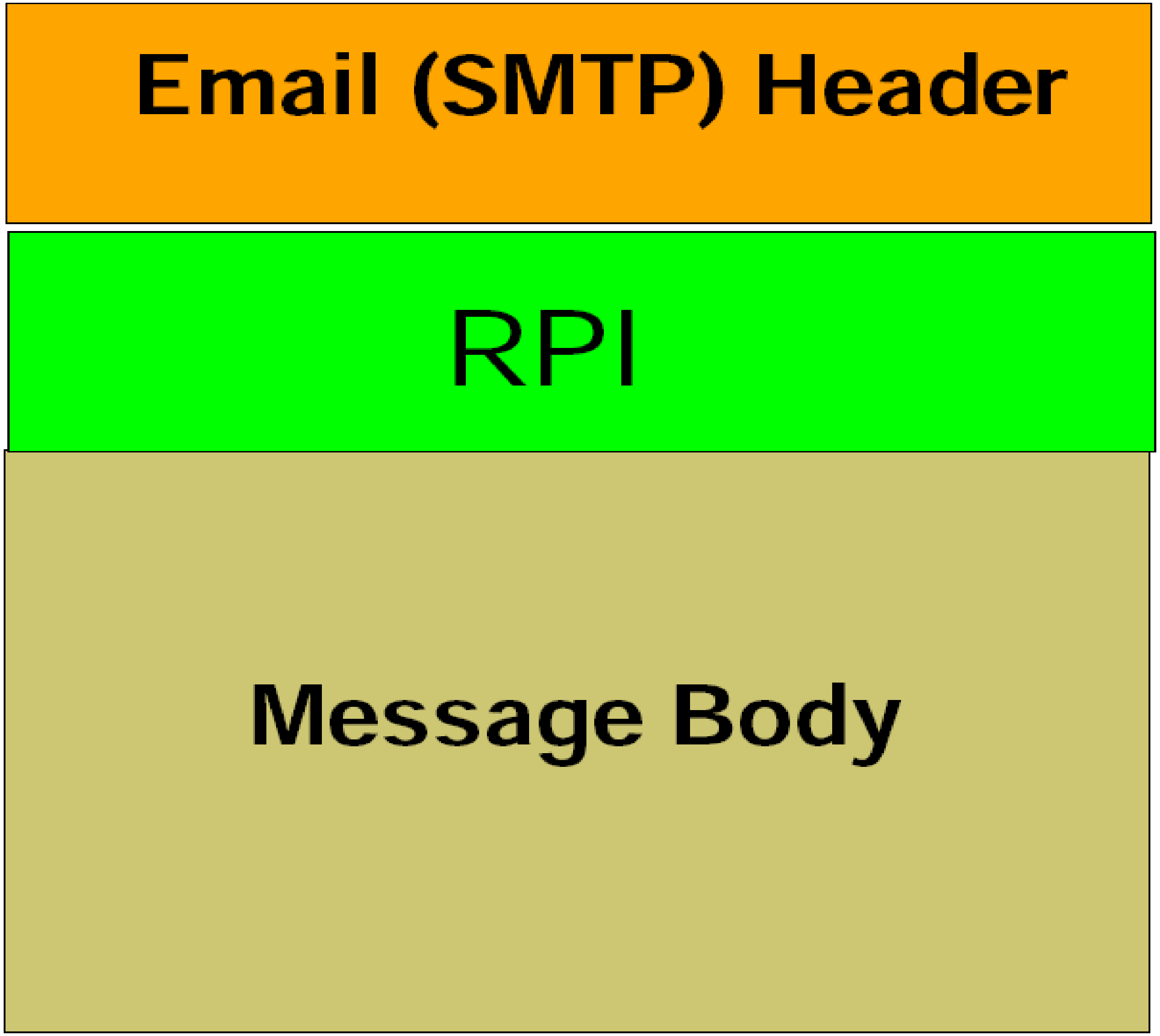
RPI

$$y_r = \mathcal{A}_{R_1}, E_{R_1}(K_1, \mathcal{A}_{R_2}, E_{R_2}(K_2, \ldots$$
$$\ldots E_{R_r}(K_r, \mathcal{A}_{\text{Alice}}, E_{\text{Alice}}(KS, r)) \ldots)).$$

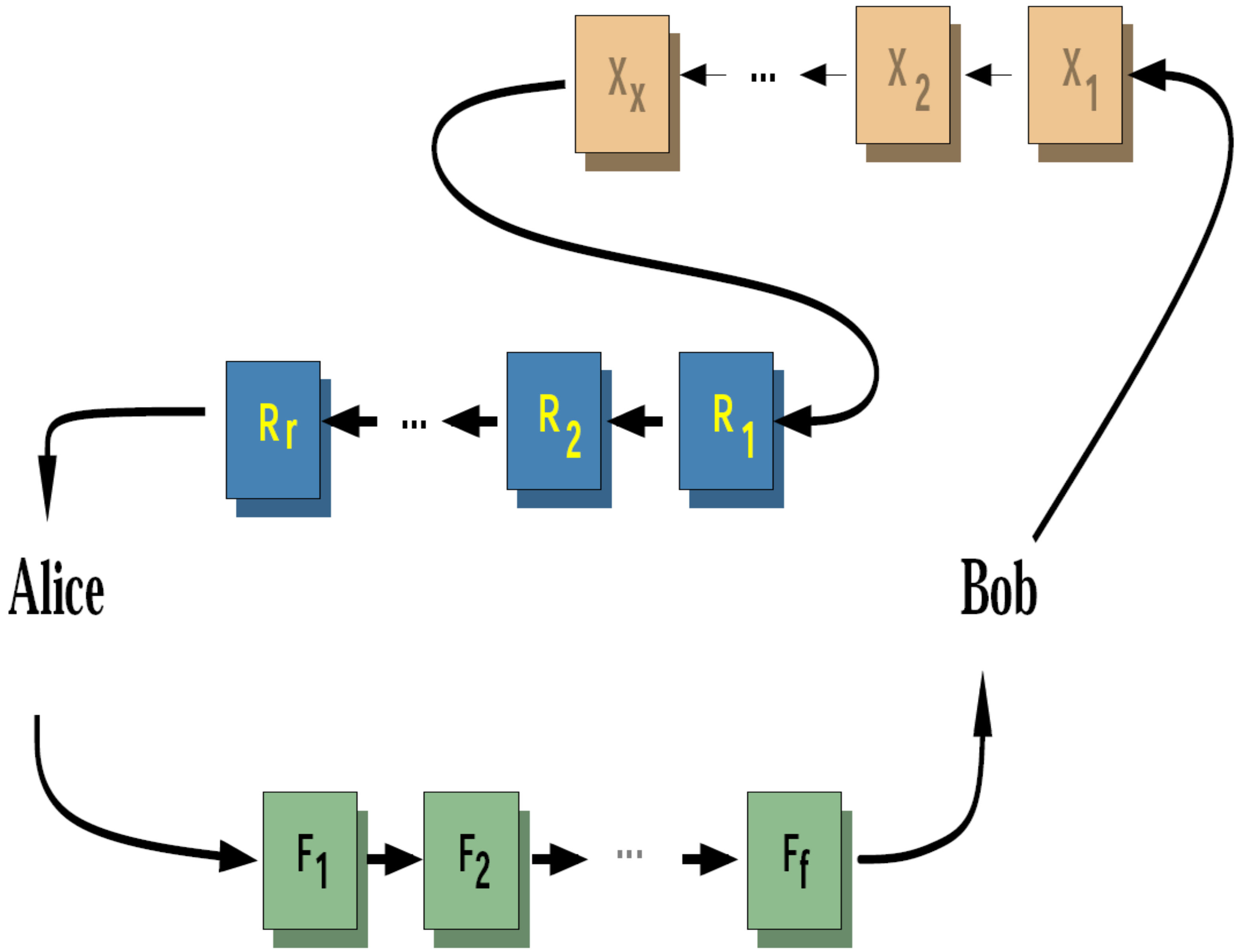
Return path information



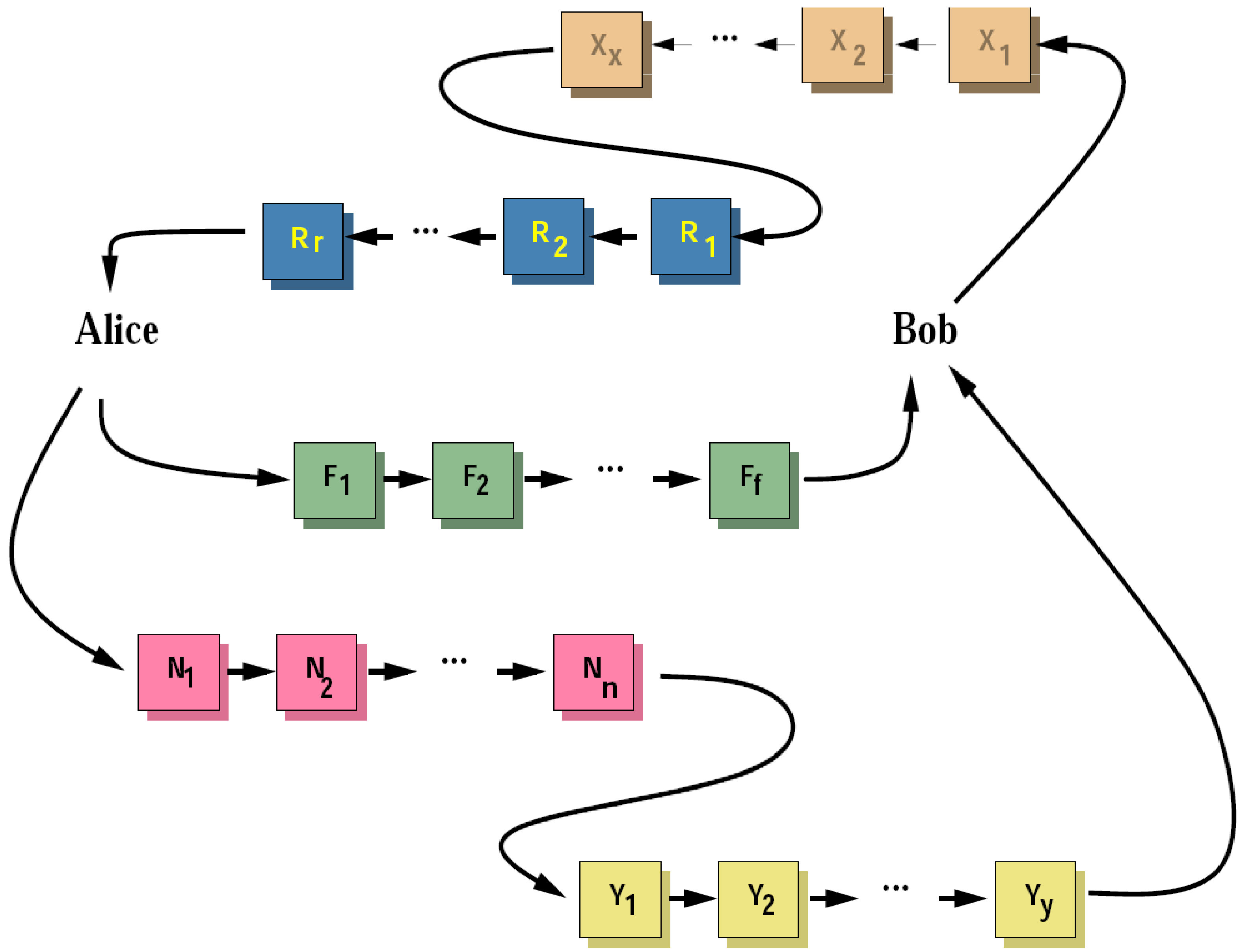
Reply message



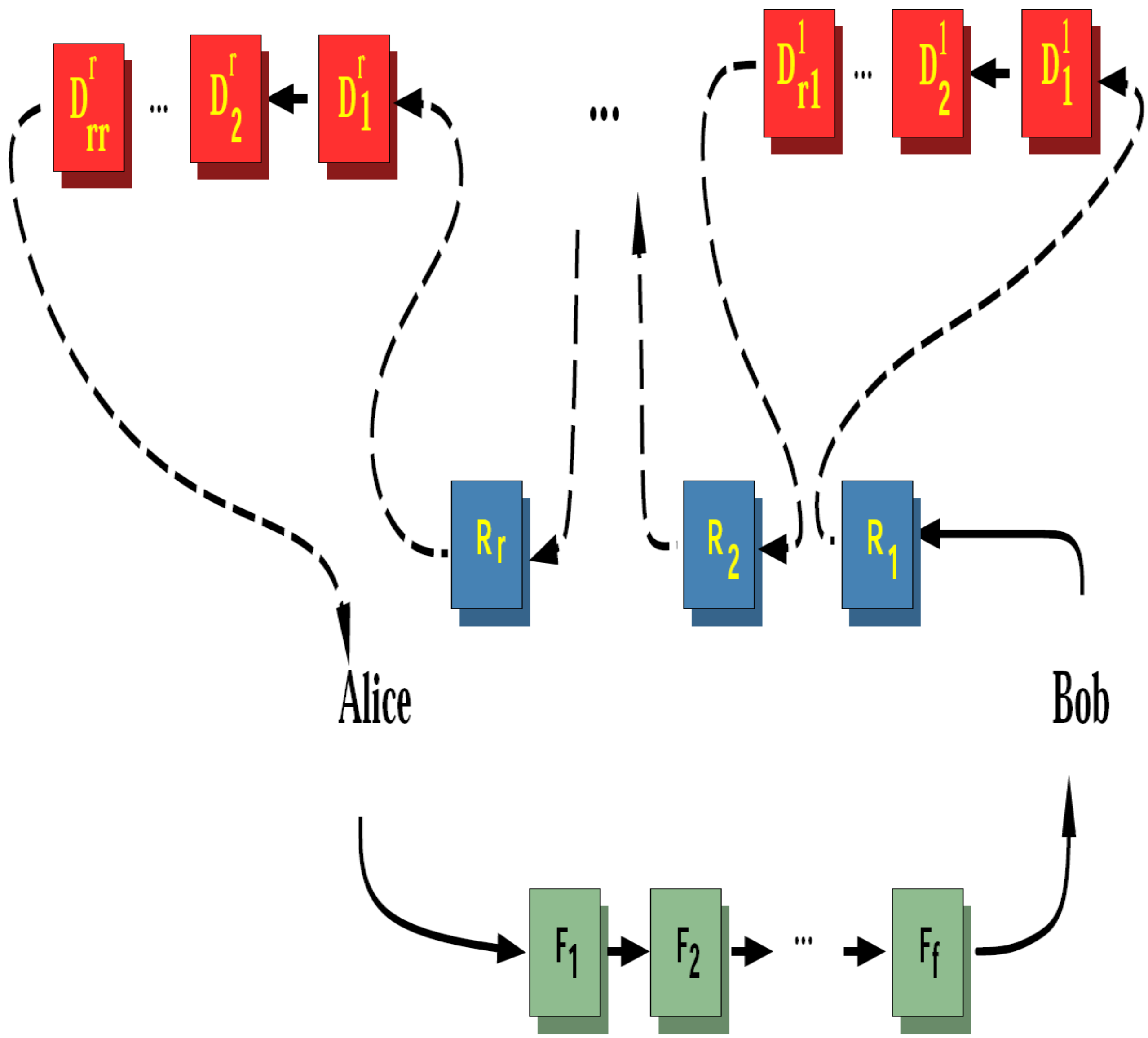
Two-way anonymity



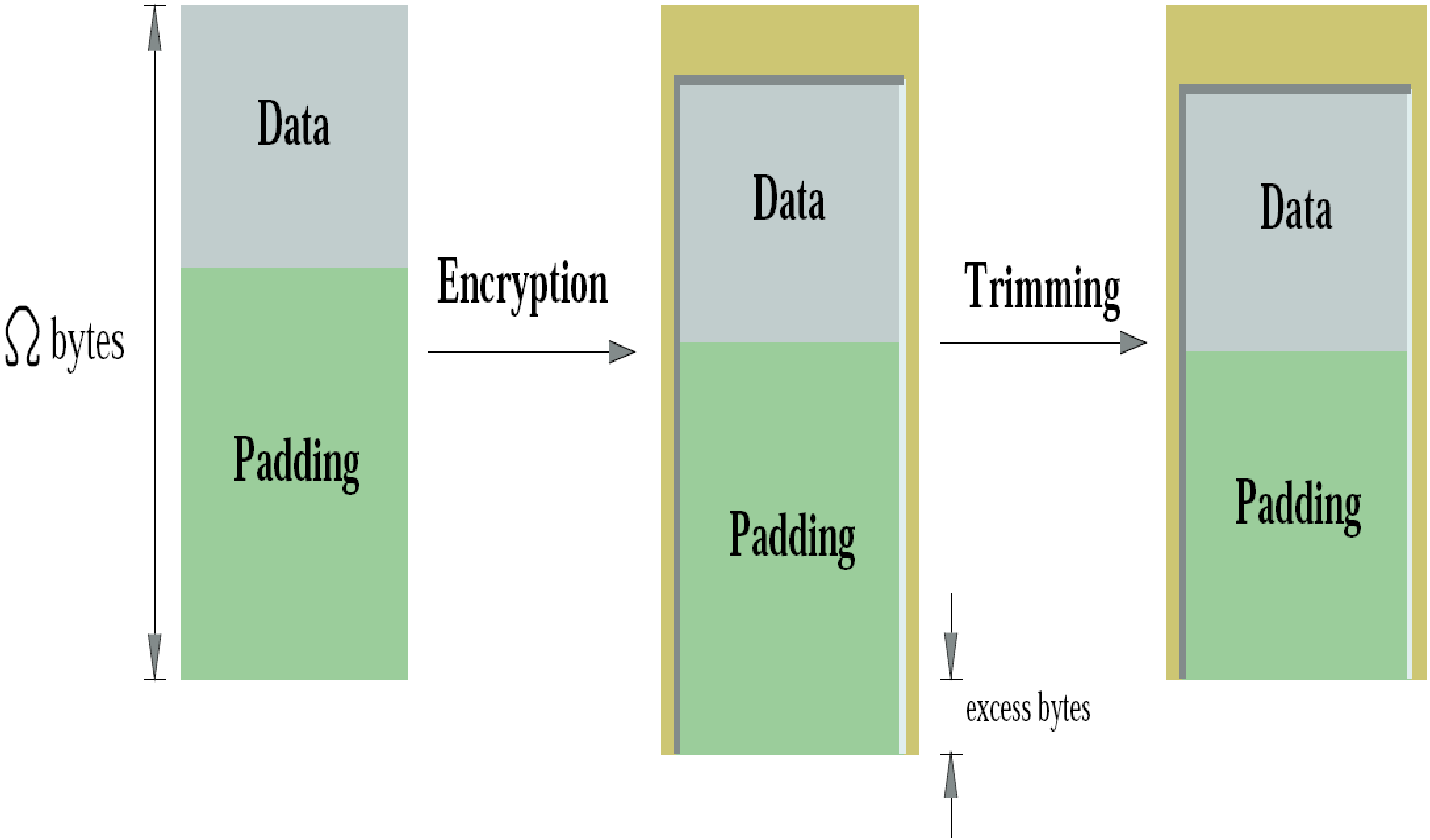
Security of replies



Inter-mix detours



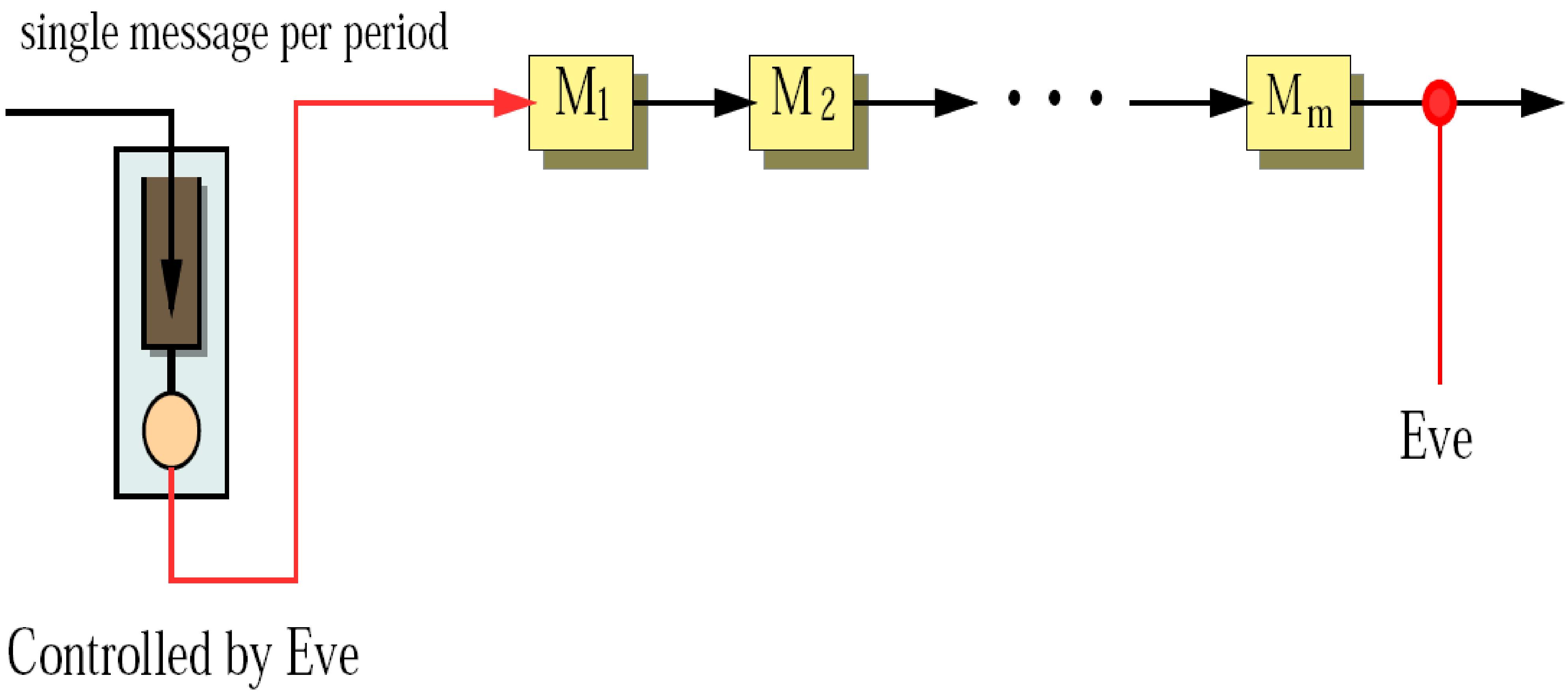
Keeping message size constant



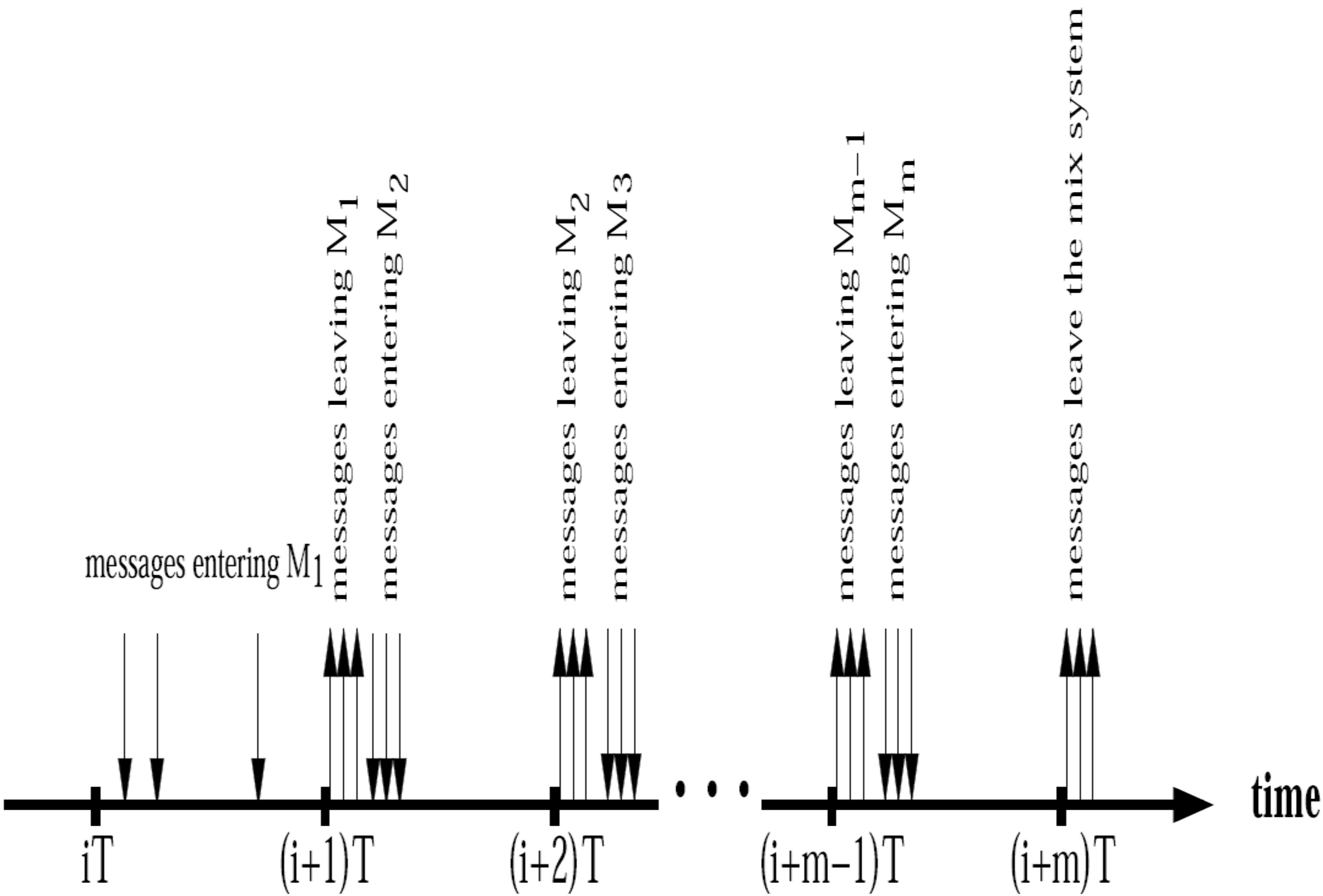
Heeding anonymity

- Fixed-path systems
- System staunchness, miss & guess factors
- Quest for confusion
  - Probabilistic deferment
  - Hybrid approach

Trickle attack



Interval batching



Probabilistic deferment

$$\mathrm{P}\{K = k\} \quad = \quad \binom{m}{k} q^{m-k} d^k \text{ where } k = 0, \ldots, m,$$

Binomial function