2009 – 2011 Cooperative Research Project: "Security Evaluation and Design of Components and Cryptographic Primitives for RFID and Sensor Networks"

The First Spring Working Meeting

India, Kolkata,

Indian Statistical Institute

April 13-15, 2009

Moderator: Miodrag Mihaljevic

Spring Working Meeting

- Venue: Indian Statistical Institute, Kolkata
- Time: April 13-15, 2009

Participants:

- Two Members of Japan-team
- Four Members of Indian-team

Agenda of the Meeting

- **Main Goal**: “Technical Discussions on Future Joint Research Activities and Regarding the 2009 Visits of India-team Members to Tokyo”
- **Lectures** on Certain Topic Candidates for joint Research Activities Related to Crypto&Coding
- **Short Technical Talks**
- **Round-table Discussions**
- Establishing **Program of the Visit and Research Directions** for Indian-team Members Visits to Japan

Lecture I

Towards Low Complexity and Highly Secure Cryptographic Primitives Which Involve Pure Randomness and Dedicated Coding

On Algebraic Representation and Security Evaluation of Certain Stream Ciphers which Involve Randomness

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Research Center for Information Security,
National Institute of Advanced Industrial Science and Technology

Spring Working Meeting of Japan-India Project

Kolkata, April 13, 2009

Roadmap

- Introduction
- Certain Stream Ciphers Based on Randomness
- Dedicated Wire-Tap Channel Coding
- Algebraic Representation of Encryption
- Security Evaluation
- Concluding Remarks

I. Introduction

previous art
and
motivation for the work

Recent Novel Designs

- Different variants of **Stream Ciphers** based on dedicated encoding and pure randomness:
- Generic Framework
- Stream Ciphers based on **Channel with Insertion and Complementing**
- Stream Ciphers based on **Wire-Tap Channel Coding**
- **Low Complexity Authentication Protocols** based on dummy and effective bits
- Above novel designs originate from the HB class of authentication protocols

Very Recent References (1)

- [1] M. Mihaljevic and H. Imai, **"An Approach for Stream Ciphers Design Based on Joint Computing over Random and Secret Data"**, *COMPUTING*, accepted for publication, 2009. (Impact Factor: 0.949)
- [2] M. Mihaljevic, **"A Framework for Stream Ciphers Based on Pseudorandomness, Randomness and Error-Correcting Coding**", in *Enhancing Crypto-Primitives with Techniques from Coding Theory*, Editors B. Preneel and S. Dodunekov, Vol. in the Series *Information and Communication Security*, IOS Press, Amsterdam, 23 pages, to appear 2009.
- [3] M. Mihaljevic and H. Imai, **"A Stream Cipher Design Based on Embedding of Random Bits"**, *IEEE 2008 Int. Symp. on Inform. Theory and its Appl. - ISITA2008*, Auckland, New Zealand, Dec. 7-10, 2008, Proceedings, pp. 1497-1502. (ISBN: 978-1-4244-2069-8; copyright2008 IEEE)

Very Recent References (2)

- [4] M. Mihaljevic and H. Imai, **"A Stream Ciphering Approach Based on the Wire-Tap Channel Coding"**, *8th Central European Conference on Cryptography - CECC 2008*, Graz, Austria, July 2-4, 2008, Conference Records, pp. 16-18.
- [5] M. Mihaljevic, **"A Framework for Stream Ciphers Based on Pseudorandomness, Randomness and Error-Correcting Coding"**, Invited Talk at NATO Advanced Research Workshop "*Enhancing Crypto-Primitives with Techniques from Coding Theory*", 6 - 9 October 2008.
- [6] M. Mihaljevic, H. Watanabe and H. Imai, **"A Cellular Automata Based HB#-like Low Complexity Authentication Technique"**, *IEEE 2008 Int. Symp. on Inform. Theory and its Appl. - ISITA2008*, Auckland, New Zealand, Dec. 7-10, 2008, Proceedings, pp. 1355-1360. (ISBN: 978-1-4244-2069-8; copyright2008 IEEE)

Some Earlier Results on Crypto&Coding

(there is a number of other results achieved in the period 2005-2008)

- [7] M. Mihaljevic, M. Fossorier and H. Imai, **"Key Management with Minimized Secret Storage Employing an Erasure Channel Approach"**, *IEEE Communications Letters*, vol. 9, pp. 741-743, Aug. 2005. (Impact Factor: 0.922)
- [8] M. Fossorier, M. Mihaljevic, H. Imai, Y. Cui and K. Matsuura, **"An Algorithm for Solving the LPN Problem and its Application to Security Evaluation of the HB Protocols for RFID Authentication",** *Lecture Notes in Computer Science*, vol. 4329, pp. 48-62, Dec. 2006. (Impact Factor: ~ 0.5)
- [9] M. Mihaljevic, **"Generic framework for secure Yuen 2000 quantum-encryption employing the wire-tap channel approach",** *Physical Review A*, vol. 75, no. 5, pp. 052334-1-5, May 2007. (Impact Factor: ~ 3.0)
- [10] M. Fossorier, M. Mihaljevic and H. Imai, **"Modeling Block Encoding Approaches for Fast Correlation Attack",** *IEEE Transactions on Information Theory*, vol. 53, no. 12, pp. 4728-4737, Dec. 2007. (Impact Factor: 2.183)

Some Previous Results on Randomized Encryption

- [11] R. Rivest and T. Sherman, **"Randomized Encryption Techniques",** *Advances in Cryptology: Proceedings of CRYPTO '82*, Plemum, New Yourk, pp. 145-163, 1983.
- [12] N.J.A. Sloane, **"Error-correcting codes and Cryptography",** *Cryptologia*, vol. 6, pp. 128-153, 1982.
- [13] O. Kara and I. Erguler, **"A New Approach to Keystream Based Cryptosystems",** *SASC 2008*, Workshop Record, pp. 205-221, Feb.

Motivation for the Work

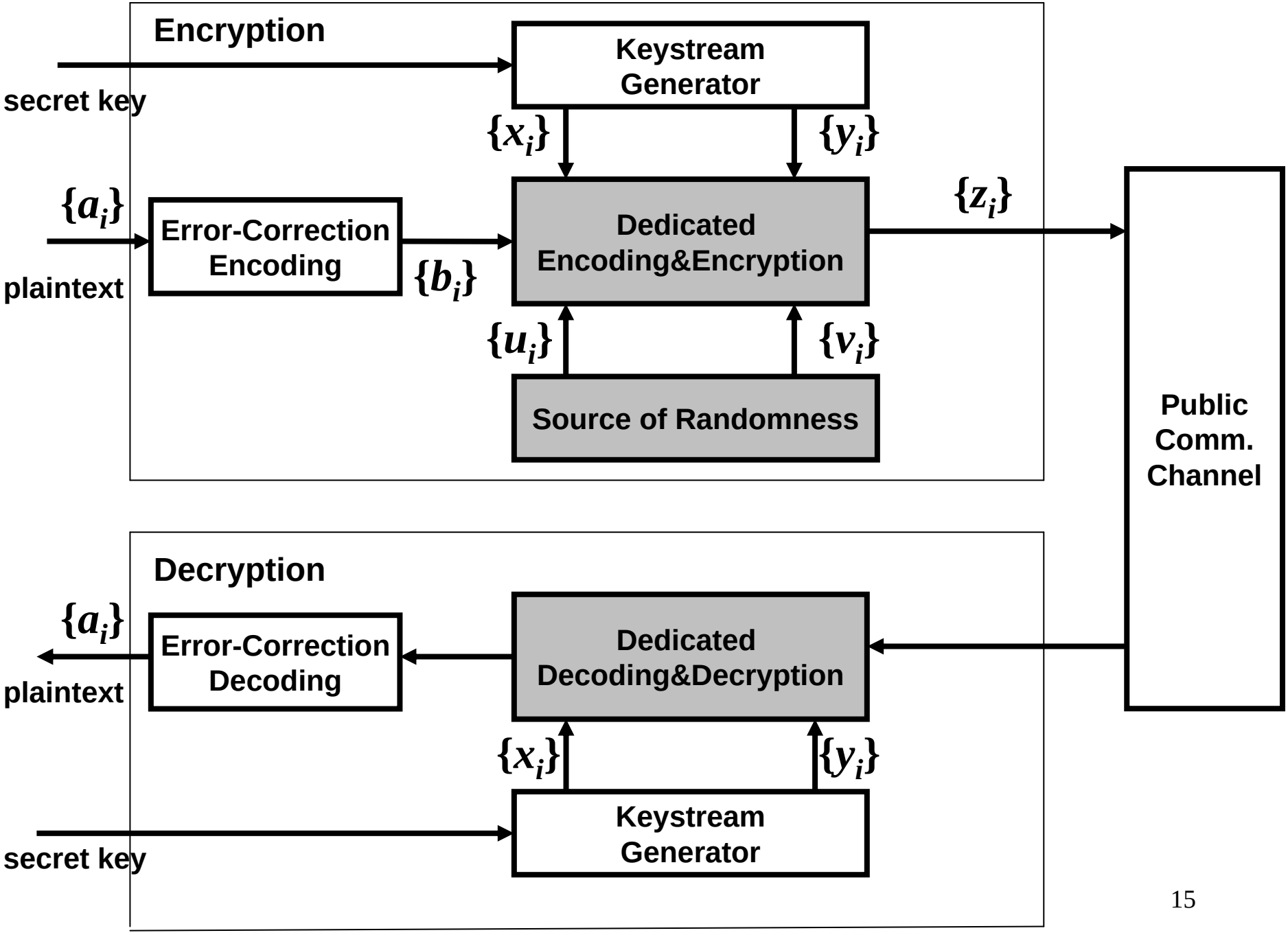
- **Establishing algebraic model** of certain stream ciphers which involve randomness and dedicated homophonic encoding.
- **Security evaluation of the established algebraic model**.

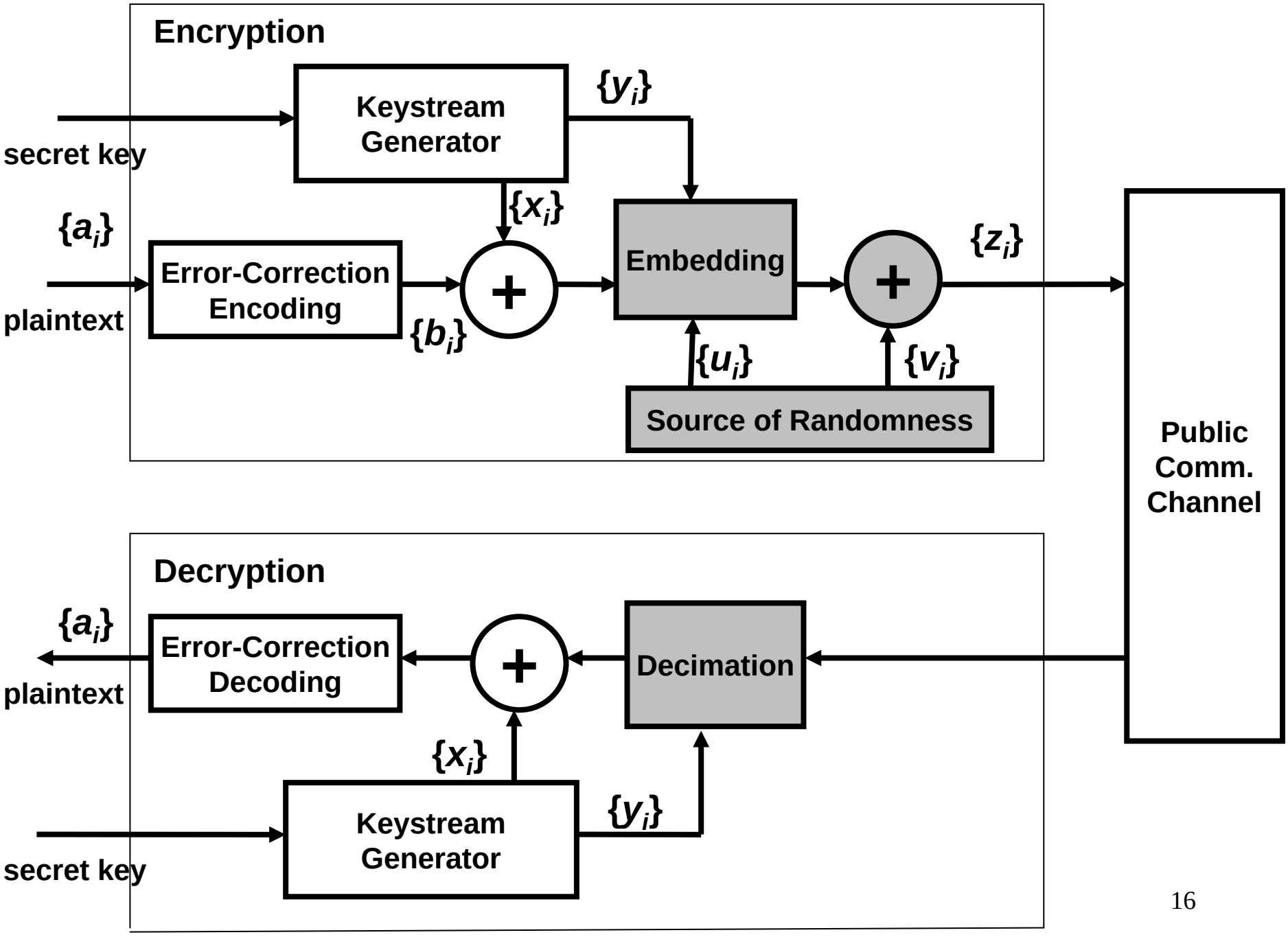
II. Certain Stream Ciphers Based on Randomness

-a generic scheme

-a scheme based on simple embedding: Stream Cipher I

-a wire-tap channel coding based scheme: Stream Cipher II


Encryption
secret key
Keystream Generator
$\{x_i\}$
$\{y_i\}$
$\{a_i\}$
plaintext
Error-Correction Encoding
$\{b_i\}$
Dedicated Encoding&Encryption
$\{z_i\}$
$\{u_i\}$
$\{v_i\}$
Source of Randomness
Public Comm. Channel
Decryption
$\{a_i\}$
plaintext
Error-Correction Decoding
Dedicated Decoding&Decryption
$\{x_i\}$
$\{y_i\}$
Keystream Generator
secret key


Encryption
Keystream Generator
$\{y_i\}$
secret key
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Error-Correction Encoding
Embedding
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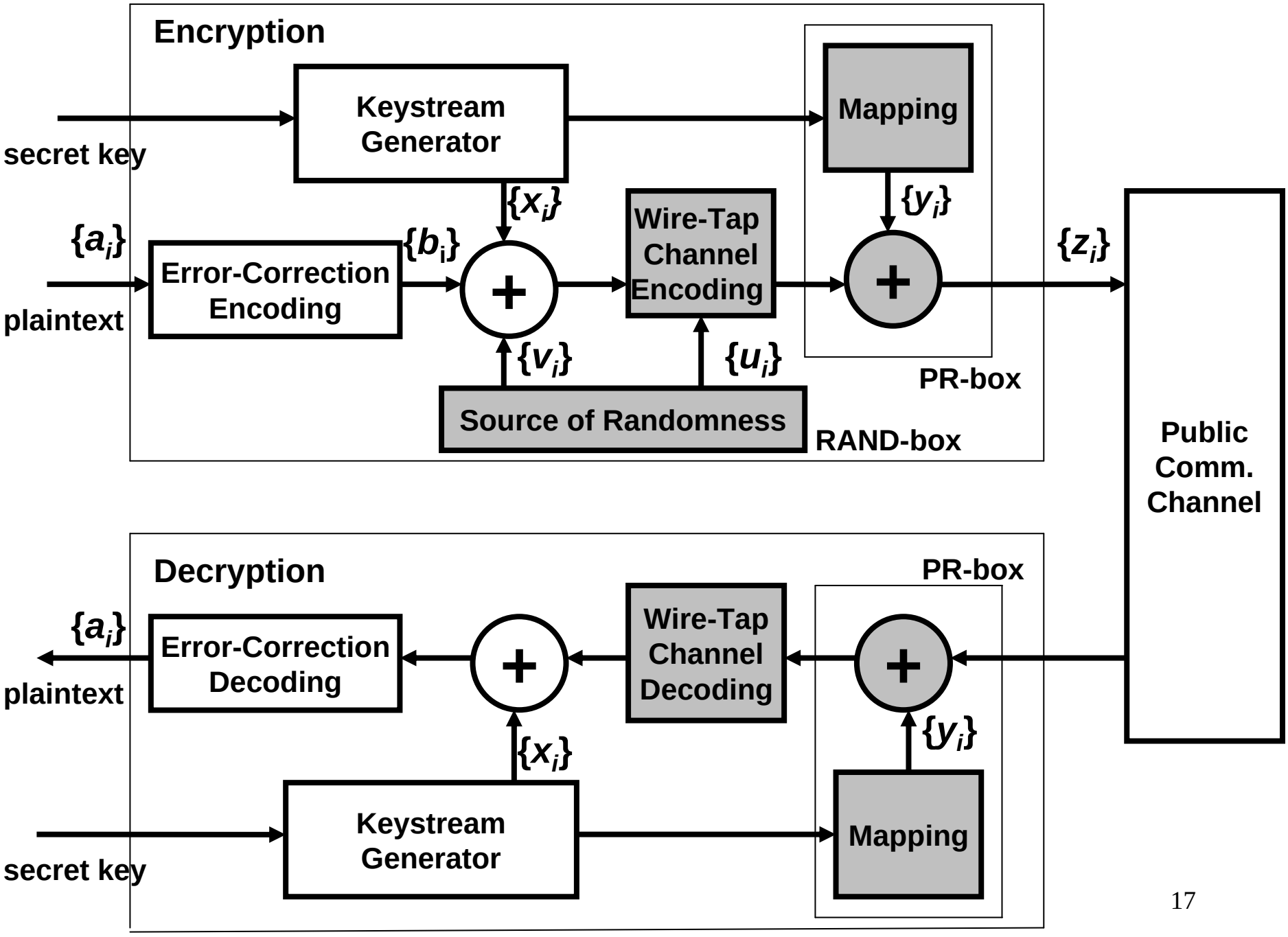
plaintext
$\{b_i\}$
$\{u_i\}$
$\{v_i\}$
Source of Randomness
Public Comm. Channel
Decryption
$\{a_i\}$
Error-Correction Decoding
Decimation
plaintext
$\{x_i\}$
Keystream Generator
$\{y_i\}$
secret key


Encryption
Keystream Generator
secret key
Mapping
{x_i}
{y_i}
{a_i}
{b_i}
Error-Correction Encoding
plaintext
Wire-Tap Channel Encoding
{z_i}
{v_i}
{u_i}
PR-box
Source of Randomness
RAND-box
Public Comm. Channel
Decryption
PR-box
{a_i}
Error-Correction Decoding
plaintext
Wire-Tap Channel Decoding
{x_i}
{y_i}
Keystream Generator
secret key
Mapping

III. Dedicated Wire-Tap Channel Coding

Coding Method and Selection of the Code

Coding Method (1)

We consider a generic approach for wire-tap channel coding as follows.

- To transmit m-bit message we first select a (n, k) code C such that $m \leq n - k$.

- Out of the 2^{n-k} cosets of C, we choose 2^m cosets and let each message correspond to a chosen coset.

- The selection of the cosets is done in a linear fashion as follows:

(a) Suppose $\mathbf{G}$ is a generator matrix for C with rows $\mathbf{g}_1$, $\mathbf{g}_2$, ..., and $\mathbf{g}_k$.

(b) We select m linearly independent vectors $\mathbf{h}_1$, $\mathbf{h}_2$, ..., $\mathbf{h}_m$, from $\{0,1\}^n \backslash C$.

(c) The coset corresponding to a m-bit message $\mathbf{s} = [s_1, s_2, ..., s_m]$ is determined as follows:

$$\mathbf{s} \rightarrow s_1\mathbf{h}_1 \oplus s_2\mathbf{h}_2 \oplus ... \oplus s_m\mathbf{h}_m \oplus C. \qquad (1)$$

Coding Method (2)

The above correspondence is deterministic, but the encoding has a random component in the selection of the employed codeword. The transmitted word $\mathbf{c}$ is specified as follows:

$$\mathbf{c} = s_1\mathbf{h}_1 \oplus s_2\mathbf{h}_2 \oplus ... \oplus s_m\mathbf{h}_m \oplus u_1\mathbf{g}_1 \oplus u_2\mathbf{g}_2 \oplus ... \oplus u_k\mathbf{g}_k \quad (1)$$

where $\mathbf{u} = [u_1, u_2, ..., u_k]$ is an uniformly random k-bit vector and in a particular case $k = n - m$.

The overall encoding operation can be described as the following. Let $\mathbf{G}^*$ be the $m \times n$ matrix with rows $\mathbf{h}_1, \mathbf{h}_2, ..., \mathbf{h}_m$. Then

$$\mathbf{c} = [\mathbf{su}] \begin{bmatrix} \mathbf{G}^* \\ \mathbf{G} \end{bmatrix} \quad (2)$$

Selection of the Code

For an arbitrary m-bit message $\mathbf{S} = \mathbf{s}$, the transmitted word belongs to $\mathbf{sG}^* \oplus C$. Since the cosets of C cover the entire space $\{0,1\}^n$, the attacker receives vector $\mathbf{Z}$ which belongs to some coset of C for example $\mathbf{rG}^* \oplus C$. If $\mathbf{e}$ denotes the error vector introduced by the wire-tapper's BSC(p), we have for $1 \leq i \leq 2^k$:

$$\text{Prob}\{Z \in \mathbf{rG}^* \oplus C\} = \text{Prob}\{\mathbf{e} \in (\mathbf{u} \oplus \mathbf{s})\mathbf{G}^* \oplus C\} = \text{Prob}\{\mathbf{e} \in \mathbf{w} \oplus C\}\ , \tag{1}$$

for some n-tuple $\mathbf{w}$. Accordingly, the following criterion for selecting the code C provides security of the message: Select C such that for any n-tuple $\mathbf{w}$, the following is valid:

$$\text{Prob}\{\mathbf{e} \in \mathbf{w} \oplus C\} \to 2^{-k}, \ \ as \ \ n \to \infty. \tag{2}$$

The above condition in conjunction with (10) implies that for an attacker it is equally likely to find $\mathbf{Z}$ in any coset of C given any message $\mathbf{S}$. Note that, assuming all $\mathbf{S} = \mathbf{s}$ are equally likely *a priori*, $\text{Prob}\{\mathbf{Z} \in \mathbf{rG}^* \oplus C\}$ is independent of $\mathbf{r}$: Hence,

$$\text{Prob}\{\mathbf{S} = \mathbf{s} | \mathbf{Z} \in \mathbf{rG}^* \oplus C\} \to 2^{-k}\ , \tag{3}$$

implies the security.

IV. Algebraic Representation of the Encryption

Stream Cipher I: Encryption Algorithm

1. Encode $\mathbf{a}_l \in \{0,1\}^\ell$ into the codeword $C(\mathbf{a}_l) \in \{0,1\}^m$ employing the selected ECC suitable for a binary symmetric channel with the crossover probability η.

2. Employing the output vector $\mathbf{x}_t \in \{0,1\}^m$ from the keystream generator compute $C(\mathbf{a}_t) \oplus \mathbf{x}_t$, where $\oplus$ denotes bit-by-bit $mod 2$ addition.

3. Generate by the RAND-box a random vector $\mathbf{u}_t \leftarrow \{0,1\}^{n-m}$ and perform psudorandom embedding (controlled by the keystream generator) of the bits from the vectors $C(\mathbf{a}_t) \oplus \mathbf{x}_t$ and $\mathbf{u}_t$ as follows: $(C(\mathbf{a}_t) \oplus \mathbf{x}_t || \mathbf{u}_t)\mathbf{P}_t$, where $\mathbf{P}_t$ is a permutation matrix (selected according to the keystream generator output $\mathbf{y}_t$) which corresponds to the considered embedding and $||$ denotes concatenation.

4. Generate by the RAND-box a random $\mathbf{v}_t \leftarrow \mathrm{Ber}_{n,\eta}$ and generate the ciphertext vector as follows:

$$\mathbf{z}_t = (C(\mathbf{a}_t) \oplus \mathbf{x}_t || \mathbf{u}_t)\mathbf{P}_t \oplus \mathbf{v}_t \ . \qquad (1)$$

Stream Cipher I: Decryption Algorithm

1. Perform decimation of $\mathbf{z}_t$ corresponding to the embedding performed in the encryption step 3 as follows:

$$\mathbf{z}_t\mathbf{P}_t^{-1} = (C(\mathbf{a}_t) \oplus \mathbf{x}_t||\mathbf{u}_t) \oplus \mathbf{v}_t\mathbf{P}_t^{-1}) \ , \qquad (1)$$

$$tcat_m(\mathbf{z}_t\mathbf{P}_t^{-1}) = C(\mathbf{a}_t) \oplus \mathbf{x}_t \oplus tcat_m(\mathbf{v}_t\mathbf{P}_t^{-1}) \ , \ (2)$$

where $\mathbf{P}_t^{-1}$ denotes the inverse permutation of $\mathbf{P}_t$ and $tcat_m(\cdot)$ denotes truncating of the argument to the first m bits.

2. Employing the output vector $\mathbf{x}_t \in \{0,1\}^m$ from the keystream generator compute

$$tcat_m(\mathbf{z}_t\mathbf{P}_t^{-1}) \oplus \mathbf{x}_t = C(\mathbf{a}_t) \oplus tcat_m(\mathbf{v}_t\mathbf{P}_t^{-1}) \ . \ (3)$$

3. Perform decoding $C^{-1}(\cdot)$ of the employed ECC and recover $\mathbf{a}_t$ according to the following:

$$\mathbf{a}_t = C^{-1}(C(\mathbf{a}_t) \oplus tcat_m(\mathbf{v}_t\mathbf{P}_t^{-1})) \ . \qquad (4)$$

Stream Cipher II: Encryption Algorithm

1. Encode $\mathbf{a}_t \in \{0,1\}^\ell$ into the codeword $\mathbf{b} = C(\mathbf{a}_t) \in \{0,1\}^m$ employing the selected ECC suitable for a binary symmetric channel with the crossover probability η.

2. Employing the output vectors $\mathbf{x}_t \in \{0,1\}^m$ from the keystream generator and $\mathbf{v}_t$ from RAND-box compute $\mathbf{b}_t \oplus \mathbf{x}_t \oplus \mathbf{v}_t$, where $\oplus$ denotes bit-by-bit $mod2$ addition, and $\mathbf{v}_t \leftarrow \mathrm{Ber}_{m,\eta}$.

3. Generate by the RAND-box a random vector $\mathbf{u}_t \leftarrow \{0,1\}^{n-m}$ and perform the selected wire-tap channel coding $C_W(\cdot)$ which provides the codeword $C_W(\mathbf{b}_t \oplus \mathbf{x}_t \oplus \mathbf{v}_t, \mathbf{u}_t)$ as an n-dimensional binary vector.

4. Employ $\mathbf{y}_t \in \{0,1\}^n$ and generate the ciphertext vector as follows:

$$\mathbf{z}_t = C_W(\mathbf{b}_t \oplus \mathbf{x}_t \oplus \mathbf{v}_t, \mathbf{u}_t) \oplus \mathbf{y}_t \ . \qquad (1)$$

Stream Cipher II: Decryption Algorithm

1. Calculate:

$$\mathbf{z}_t \oplus \mathbf{y}_t = C_W(\mathbf{b}_t \oplus \mathbf{x}_t \oplus \mathbf{v}_t, \mathbf{u}_t) \; . \qquad (1)$$

2. Perform decoding $C_W^{-1}(\cdot)$, corresponding to the employed wire-tap channel encoding, as follows:

$$C_W^{-1}(\mathbf{z}_t \oplus \mathbf{y}_t) = \mathbf{b}_t \oplus \mathbf{x}_t \oplus \mathbf{v}_t \; . \qquad (2)$$

3. Employing the output vector $\mathbf{x}_t \in \{0,1\}^m$ from the keystream generator compute

$$C_W^{-1}(\mathbf{z}_t \oplus \mathbf{y}_t) \oplus \mathbf{x_t} = C(\mathbf{a}_t) \oplus \mathbf{v}_t \; . \qquad (3)$$

4. Perform decoding $C^{-1}(\cdot)$ of the employed ECC and recover $\mathbf{a}_t$ according to the following:

$$\mathbf{a}_t = C^{-1}(C_W^{-1}(\mathbf{z}_t \oplus \mathbf{y}_t) \oplus \mathbf{x_t}) \; . \qquad (4)$$

Unified Algebraic Model

for Stream Ciphers I & II

For the Stream Cipher I, the following algebraic model can be shown:

$$\mathbf{z} = (\bigoplus_{i=1}^{m}(b_i \oplus x_i)\mathbf{p}_i) \oplus (\bigoplus_{i=1}^{n-m} u_i \mathbf{p}_{m+i}) \oplus \mathbf{v} \ ,$$

$$= (\bigoplus_{i=1}^{m} b_i \mathbf{p}_i) \oplus \phi(\mathbf{x}, \mathbf{u}, \mathbf{v}, \mathbf{P}) \qquad (1)$$

where $\phi(\mathbf{x}, \mathbf{u}, \mathbf{v}, \mathbf{P}) = (\bigoplus_{i=1}^{m} x_i \mathbf{p}_i) \oplus (\bigoplus_{i=1}^{n-m} u_i \mathbf{p}_{m+i} \oplus \mathbf{v})$, $\mathbf{b} = C(\mathbf{a})$, and $\mathbf{P}$ is a function of $\mathbf{y}$, i.e. $\mathbf{k}$.

For the Stream Cipher II, assuming that the linear wire-tap channel coding $C_W(\cdot)$ is employed, after the wire-tap channel encoder, we have the following:

$$\mathbf{z} = C_W(\mathbf{b} \oplus \mathbf{x} \oplus \mathbf{v}, \mathbf{u}) \oplus \mathbf{y} = (\bigoplus_{i=1}^{m} (b_i \oplus x_i \oplus v_i)\mathbf{h}_i) \oplus (\bigoplus_{i=1}^{n-m} u_i \mathbf{g}_i) \oplus \mathbf{y} \quad (1)$$

$$= (\bigoplus_{i=1}^{m} b_i \mathbf{h}_i) \oplus \phi(\mathbf{x}, \mathbf{y}, \mathbf{u}, \mathbf{v}, \mathbf{G}, \mathbf{G}^*) \; . \quad (2)$$

where

$$\phi(\mathbf{x}, \mathbf{y}, \mathbf{u}, \mathbf{v}, \mathbf{G}, \mathbf{G}^*) = (\bigoplus_{i=1}^{m} x_i \mathbf{h}_i \oplus \mathbf{y}) \oplus (\bigoplus_{i=1}^{n-m} u_i \mathbf{g}_i) \oplus (\bigoplus_{i=1}^{m} v_i \mathbf{h}_i). \quad (3)$$

Proposition 1. In the both Stream Ciphers I and II, the ciphertext $\{z_t\}$ can be represented as follows:

$$\mathbf{z} = f_i(\mathbf{a}) \oplus \phi_i(\mathbf{k}, \mathbf{r}) \ , \ \ i = I, II \ , \qquad (1)$$

where for the Stream Cipher I

$$f_I(\cdot) = \bigoplus_{i=1}^{m} b_i \mathbf{p}_i \ , \ \ \phi_I(\cdot) = (\bigoplus_{i=1}^{m} x_i \mathbf{p}_i) \oplus (\bigoplus_{i=1}^{n-m} u_i \mathbf{p}_{m+i}) \oplus \mathbf{v} \ , \qquad (2)$$

and for the Stream Cipher II

$$f_{II}(\cdot) = \bigoplus_{i=1}^{m} b_i \mathbf{h}_i \ , \ \ \phi_{II}(\cdot) = (\bigoplus_{i=1}^{m} x_i \mathbf{h}_i \oplus \mathbf{y}) \oplus (\bigoplus_{i=1}^{n-m} u_i \mathbf{g}_i \oplus \bigoplus_{i=1}^{m} v_i \mathbf{h}_i), \qquad (3)$$

and where $\mathbf{b} = C(\mathbf{a})$, $\mathbf{k}$ denotes secret key, $\mathbf{r}$ is a random vector, and $\mathbf{P} = [\mathbf{p}_i]_{i=1}^{n}$ is a permutation $n \times n$ matrix, and each $\mathbf{p}_i$ is a binary n-dimensional vector with only one non-zero element.

V. Security Evaluation

LPN Problem Based Security

Indistinguishability

One of the security goals is the indistinguishability (IND): IND deals with the secrecy provided by the scheme in the following sense: An adversary must be unable to distinguish the encryption of two (chosen) plaintexts. For the IND considerations we assume the following traditional approach. An adversary is considered as a pair of algorithms $\mathcal{A} = (\mathcal{A}_1, \mathcal{A}_2)$ and they operate through two phases as follows.

Phase I. $\mathcal{A}_1$ is employed during the first phase and at the end of this phase, $\mathcal{A}_1$ outputs a pair of plaintexts $(\mathbf{x}_1, \mathbf{x}_2)$.

Phase II. One of the given plaintexts is selected with probability equal 1/2, then encrypted, and the obtained ciphertext is delivered to $\mathcal{A}_2$ - this represents $\mathcal{A}$'s challenge. The success of $\mathcal{A}$ is determined according to correctness of decision whether $\mathbf{x}_1$ or $\mathbf{x}_2$ was encrypted.

LPN Problem

Informally, Learning from Parity with Noise (LPN) problem can be described as learning an unknown k-bit vector $\mathbf{s}$ given noisy versions of its scalar product $\mathbf{a} \cdot \mathbf{s}$ with randomly selected vectors $\mathbf{a}$.

In a formal manner, the LPN problem is the problem of retrieving $\mathbf{s}$ given access to the oracle $\Pi_{s,\eta}$. For a fixed value of k, we will say that an algorithm $\mathcal{A}(T, q, \delta)$-solves the LPN problem with noise parameter η if $\mathcal{A}$ runs in time at most T, makes at most q oracle queries, and

$$\Pr\left[\mathbf{s} \leftarrow \{0,1\}^k \ : \ \mathcal{A}^{\Pi_{s,\eta}}(1^k) = s\right] \geq \delta$$

By saying that the LPN problem is hard, we mean that any efficient adversary solves it with only negligible probability. There is a significant amount of literature dealing with the hardness of the LPN problem. It is closely related to the problem of decoding a random linear code and it is NP-hard.

LPN Problem and the Indistinguishability

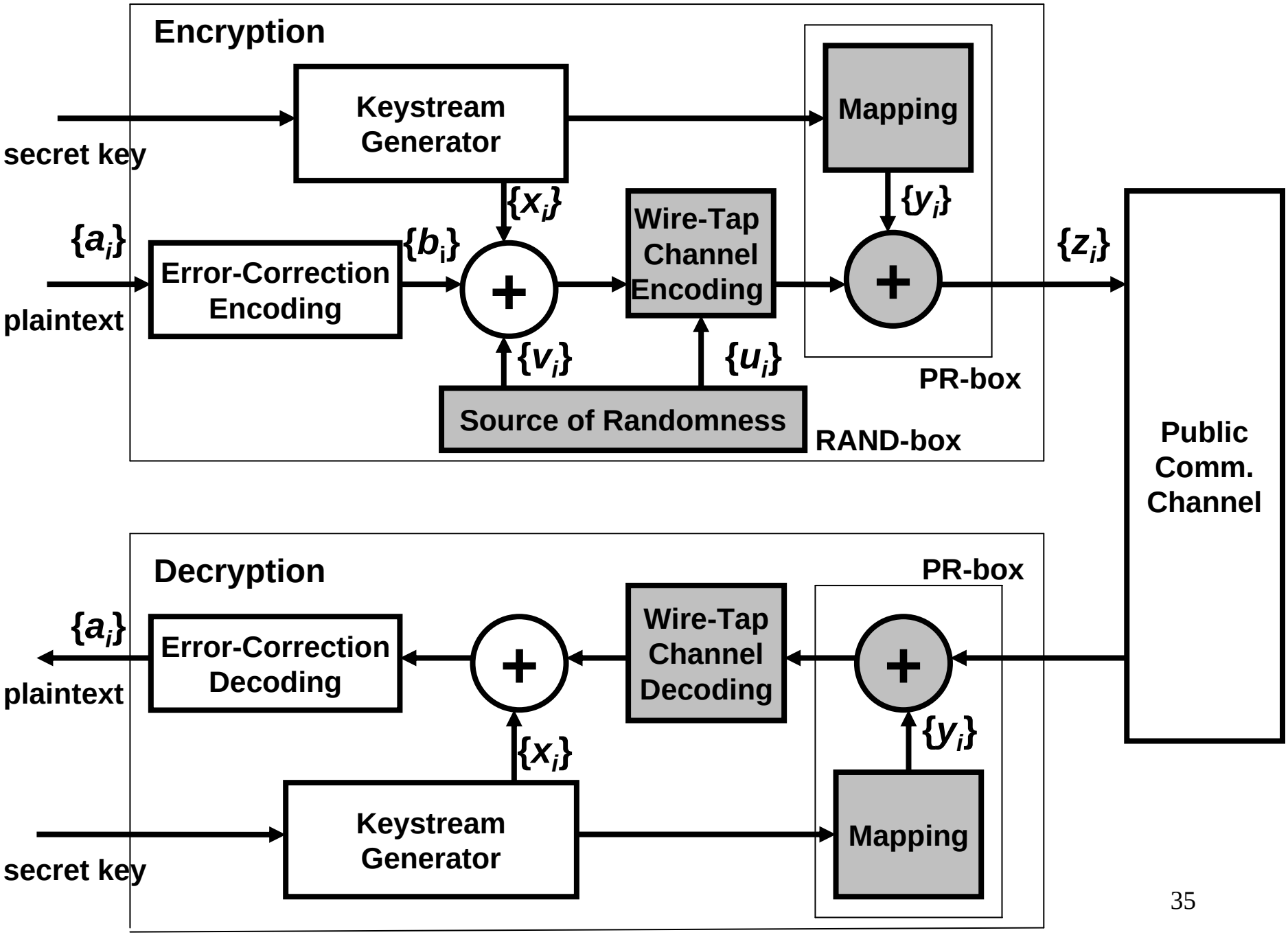
The following lemma states that the hardness of the LPN problem implies that the two oracles $\mathcal{U}_{k+1}$ and $\Pi_{s,\eta}$ are indistinguishable.

Lemma 1, [Katz, CRYPTO&Coding2007]. Assume there exists an algorithm $\mathcal{M}$ making q oracle queries, running in time T, and such that

$$\left|\Pr\left[\mathrm{s} \leftarrow \{0,1\}^k \ : \ \mathcal{M}^{\Pi_{s,\eta}}(1^k) = 1\right] - \Pr\left[\mathcal{M}^{\mathcal{U}_{k+1}}(1^k) = 1\right]\right| \geq \delta \ .$$

Then there is an algorithm $\mathcal{A}$ making $q' = O(q \cdot \delta^{-2}\log k)$ oracle queries, running in time $T' = O(T \cdot k\delta^{-2}\log k)$, and such that

$$\Pr\left[\mathbf{s} \leftarrow \{0,1\}^k \ : \ \mathcal{A}^{\Pi_{s,\eta}}(1^k) = \mathbf{s}\right] \geq \frac{\delta}{4} \ .$$


Encryption
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Decryption
PR-box
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Error-Correction Decoding
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Wire-Tap Channel Decoding
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{y_i}
Keystream Generator
secret key
Mapping

Algebraic Model of Stream Cipher II under Chosen Plaintext Attack

Corollary 1. Under the chosen plaintext attack which for each t implies $\mathbf{b}_t = \mathbf{0}$ (i.e. the all zeros vector), Proposition 1 implies:

$$\mathbf{z}_t = \mathbf{q}_t \mathbf{S} \oplus \vec{\nu_t} \ , \tag{1}$$

where

$$\mathbf{q}_t = (\bigoplus_{i=1}^{m} x_i \mathbf{h}_i \oplus \mathbf{y}_t)\mathbf{S}^{-1} \ \ , \ \ \vec{\nu_t} = (\bigoplus_{i=1}^{n-m} u_i \mathbf{g}_i) \oplus (\bigoplus_{i=1}^{m} v_i \mathbf{h}_i) \ , \tag{2}$$

and where $\mathbf{S}$ is an $n \times n$ binary matrix determined by the length k binary secret key $\mathbf{k}$, and $\mathbf{S}^{-1}$ is its inverse.

Assumption 1. For any $t = 1, 2, ...,$ $\vec{\nu_t} \leftarrow \mathrm{Ber}_{n,\eta}$, where η is the parameter.

A Statement on Stream Cipher II Security

Theorem 1. Assume there is an adversary $\mathcal{A}$, running in time T , and attacking the Stream cipher II specified by Corollary 1 and Assumption 1 with parameters (ℓ, m, k, n, η), $k = n$, in the sense of IND with advantage δ by making at most q queries to the encryption oracle. Then there is an algorithm $\mathcal{M}$ making $O(q)$ oracle queries, running in time $O(T)$, and such that

$$\left|\Pr\left[\mathrm{s} \leftarrow \{0,1\}^k \ : \ \mathcal{M}^{\Pi_{s,\eta}}(1^k) = 1\right] - \Pr\left[\mathcal{M}^{\mathcal{U}_{k+1}}(1^k) = 1\right]\right| \geq \frac{\delta}{n} \,. \tag{1}$$

VI. Concluding Notes

Main Messages of This Talk

- The talk has pointed out the **underlying algebraic structure** of certain stream ciphers which involve randomness and dedicated homophonic encoding.
- The algebraic model of the considered stream ciphers imply that **the security originates from the hardness of the LPN problem**.

Thank You Very Much for the Attention,

and

QUESTIONS Please!