Cryptosystem based on chaotic dynamics implemented with cellular automata for protection of information on network systems

Postdoctoral research project

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Abstract/Overview

The major objective of the research is the implementation of a cryptosystem with cellular automata because of their very good performances (the massive parallelism, the robustness, the structural simplicity – macroscopic evolution being in fact the reflection of microscopic evolution) and of the advantages offered by this model for the VLSI implementation.

1. CAs vs. PCAs

CAs represents a particular class of dynamical systems that enable to describe the evolution of **complex systems** with **simple rules**, without using partial differential equations. A CA consists of a regular uniform n-dimensional **array of cells** where every cell can take values either 0 or 1 and **evolve** in **discrete time steps**.

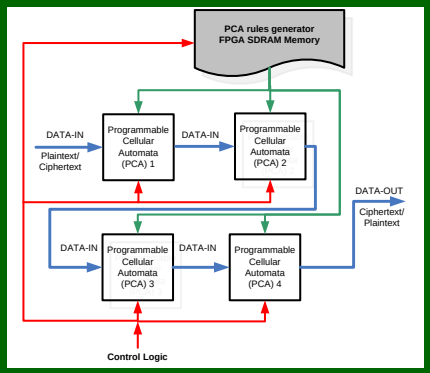
PCAs are modified CA structures, where the combinational logic of each cell is not fixed but controlled by a number of **control signals** such that **different functions** (evolution rules) can be **realized/implemented** on the **same structure**.

2. PCA based encryption algorithm

The encryption method proposed in this paper is based on the fact that the CA from class II (*dynamical systems*) exhibit periodic behaviour (each state lies in some cycles). In these cases, their evolution depends essentially of the initial state, but we can say that after a while the initial state is "forgotten", in sense that the state cannot be retrievable through analyses of the current configuration.

The proposed encryption system it is realised using a combination of 4 PCA with rules **51, 60 and 102 arranged in pipeline**. The PCA evolution rules are stored in a FPGA SDRAM memory (provide real-time keys for the cipher).

Rules	7 111	6 110	5 101	4 100	3 011	2 010	1 001	0 000
51	0	0	1	1	0	0	1	1
60	0	0	1	1	1	1	0	0
102	0	1	1	0	0	1	1	0
	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0



The block cipher (decipher) procedure can be defined as follows:

1. Load the PCA1 with one byte plaintext (ciphertext) from I/O. The initial block of the message is the initial state of the PCA1. The global configuration of the PCA4 represents the encrypted (decrypted) message.

2. Load a rule configuration control word from memory rules into the PCA1 … PCA4.

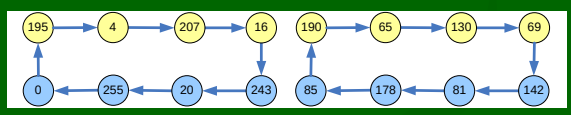
3. Run the PCA (1, 2, 3 and 4) for 1 … 7 cycles.

4. Repeat steps 2 and 3 for four times.

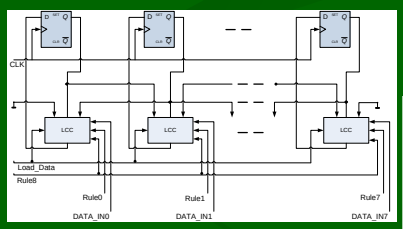
5. Send one byte ciphertext (plaintext) to I/O (from the PCA4). If not end of the plaintext (ciphertext) go to step 1. Otherwise, stop the process.

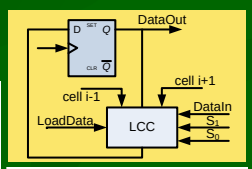
3. PCA evolution rules (51, 60 and 102)

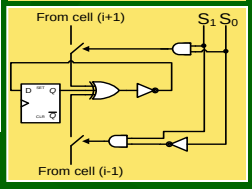
The PCA configured with the rules 51, 60 and 102 has a state-transition diagram that consists of equal cycles of even length. As an example, 8-cell PCA with rule configuration <51, 51, 60, 60, 60, 60, 51 and 51> generates cycles as depicted in below figure.



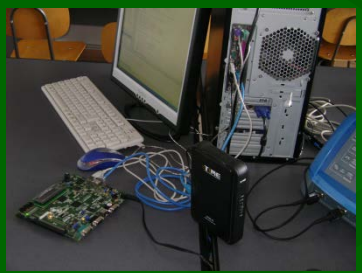
According with the CA theory, a single basic PCA cell was designed. Then, 8 cells are connected together to compose an 8-cell PCA (in this project we have 32 cells).

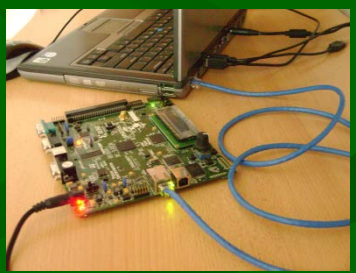






4. Testing and Results





As we depict in the next two figures, the distribution of the encrypted text is uniform in all intervals, i.e. the encrypted text is distributed almost uniformly in all ASCII intervals and not only in alphanumeric intervals.