SFLA has been proposed by MM Eusuff and KE Lansey [11], it is a population-based cooperative search algorithm inspired by natural systems. This algorithm consists of a set of frogs (each represents a solution to the problem) partitioned into different groups (memeplexes). Frogs can communicate with each other and improve their solutions by contamination (passing information). The algorithm contains local search elements performed in each group with a global information exchange. Information between different memeplexes flows through a jumping process. In each memeplex, frogs provide the best solution X_b and the worst one X_w. The frog giving the best solution in the whole population is denoted by X_g. During the evolution of a memeplex, that is, during the local exploration, the worst frog jumps to the best solution according to the following rule:

$$D = r \times (|X_b - X_w|) \quad (0 < r < 1). \tag{1}$$

$$X_{w'} = X_w + D. \tag{2}$$

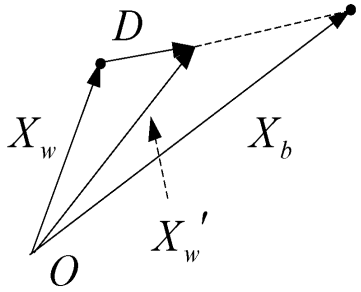


Figure 1. Frog Jump Rule [12]

In order to make sure the global exploration, the memeplexes are mixed and reorganized again to form a new population; this mechanism is repeated until a stop criterion is reached [13]. Decomposing the population into several memeplexes and doing two types of research (local and global) allowed SFLA to largely avoid the local optimum problem. Thus, we chose SFLA among other metaheuristics in order to implement it in OFDM-based cognitive radio networks.

The following code represents the behavior of the SFLA.

Step 1: Set the size *F* of population, the number *M* of memeplex and the number *N* of iterations.
Step 2: Generate a random population of *F* solutions and evaluate each solution.
Step 3: Sort the population and determine the best solution $\boldsymbol{X_g}$.
Step 4: Partition the population into *M* memeplexes.
Step 5: Local search: **for** each memeplex, **repeat** for *N* iterations:

- Determine the best solution X_b and the worst solution X_w.
- Calculate $X_{w'}$ from X_b (apply equations 1 and 2)
- **if (**$X_{w'}$ is better than X_w) **then** replace X_w by $X_{w'}$
- **else** calculate $X_{w'}$ from X_g (apply equations 1 and 2 with replacing X_b by X_g)
  - **if** ($X_{w'}$ is better than X_w) **then** replace X_w by $X_{w'}$
  - **else** Randomly generate $X_{w'}$ and replace X_w by $X_{w'}$
  - **end if**
- **end if**

Step 6: Bring together the *M* memeplexes to build again the population.
Step 7: Go to step 3 if the stop criterion is not reached.

Figure 2 shows the memeplex partitioning process.

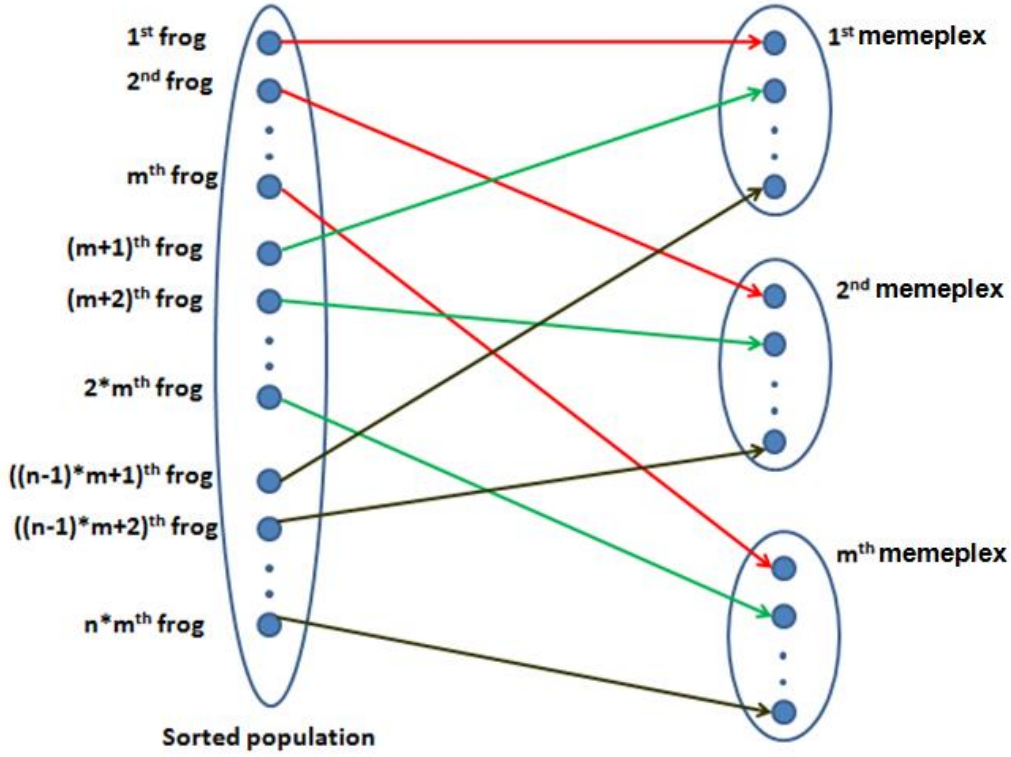


Figure 2. Memeplex partitioning process.

The population is divided into *M* memeplexes each holding *n* frogs such that $F = M \times n$. This population is sorted in descending order according to the objective function (fitness) and distributed in several different memeplexes. To improve the solutions, an independent local search is carried out for each memeplex. During the improvement of a memeplex, a new solution X_w, will be calculated from the best local solution X_b according to the rule of the frog jump. If the created individual is better than the worst solution X_w, then it replaces it. Otherwise, the same rule is applied by replacing X_b by the global solution X_g. If the new solution X_w, remains worse than X_w, then randomly generate another solution that replaces X_w.

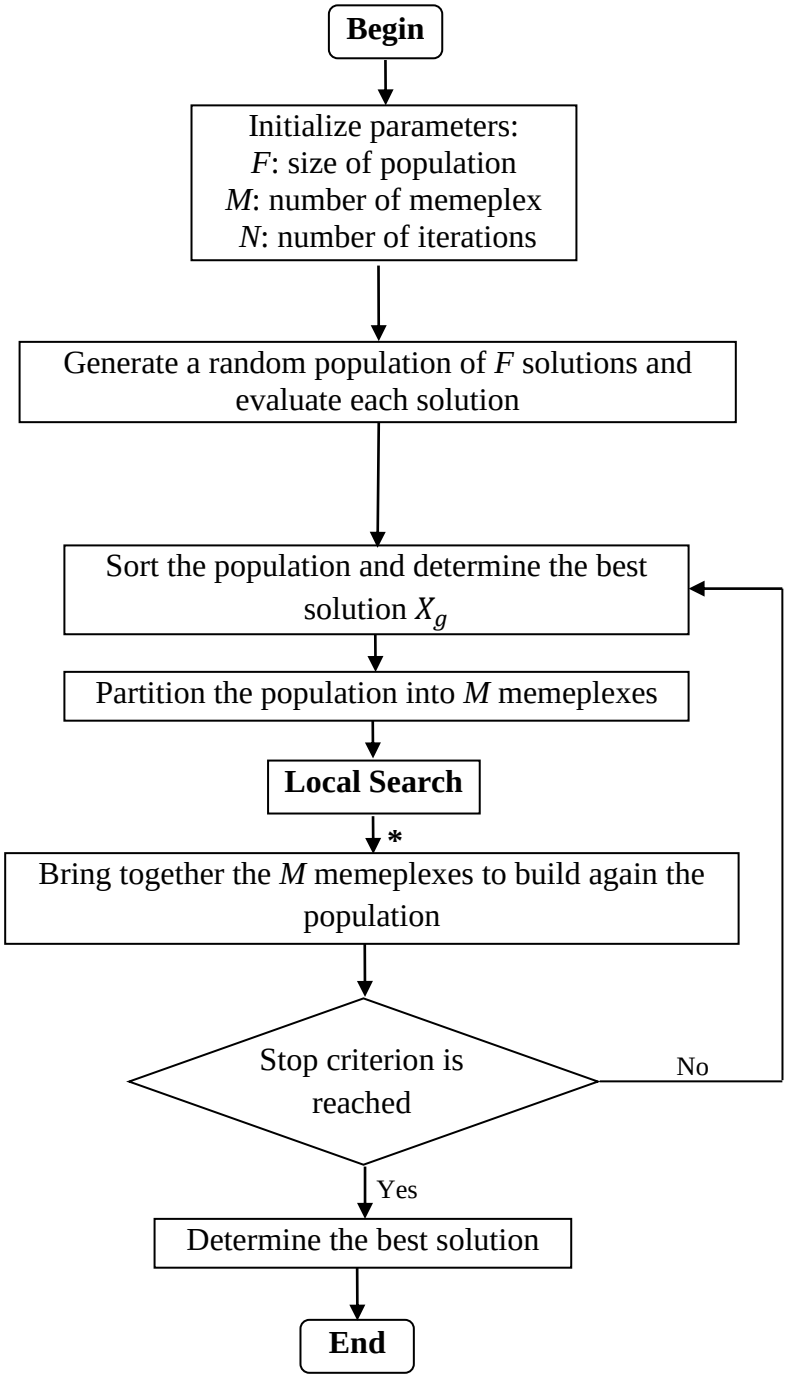
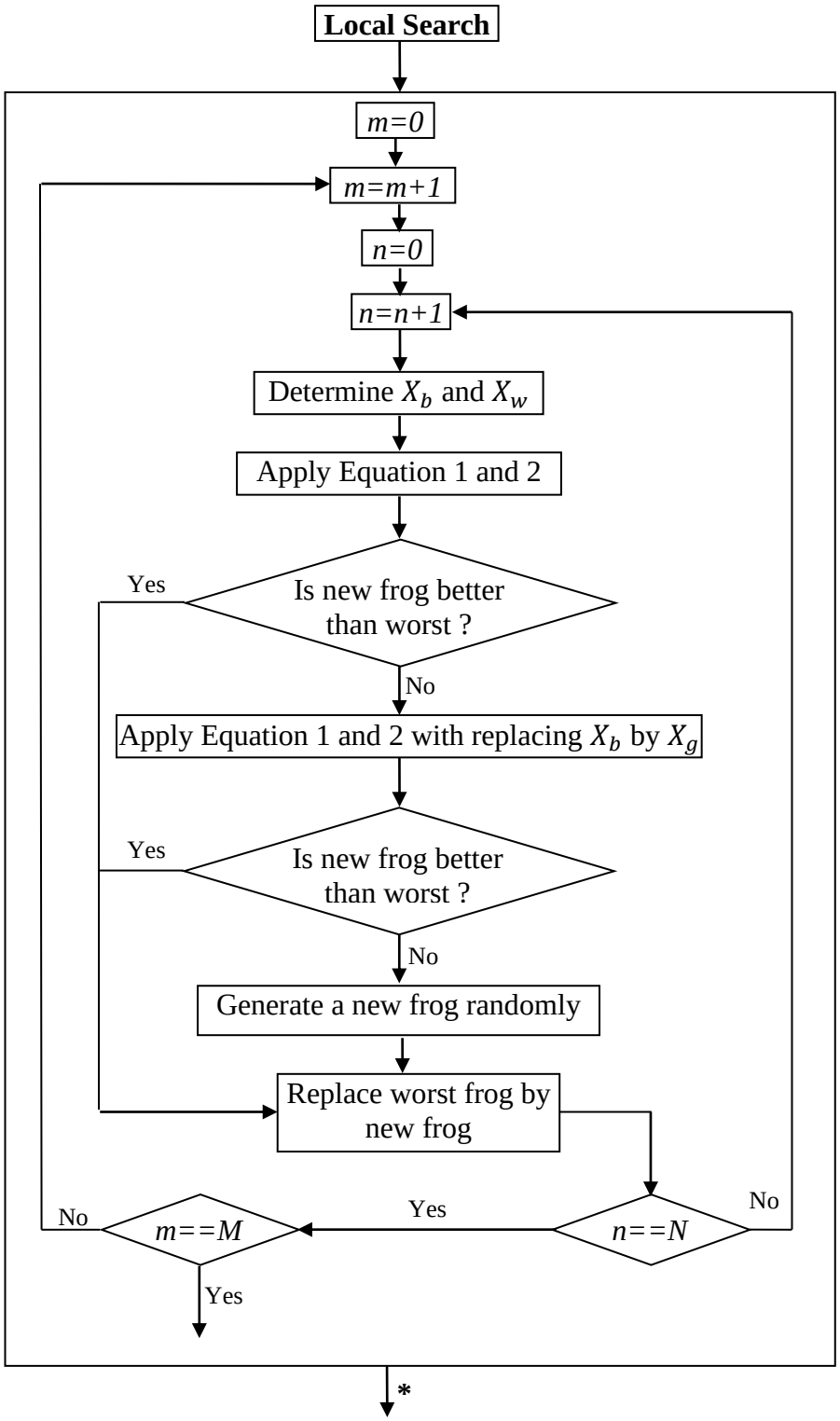


Figure 3. Methodology of our implementation using SFLA



Usually, the convergence criteria can be defined as follows:

- The relative change in the fitness of the best frog within a number of consecutive iterations is less than to a certain predefined threshold.
- The specified number of iterations is reached.

The SFLA will stop when one of the above criteria is achieved first.

[11] Eusuff MM, Lansey KE. Optimization of water distribution network design using the shuffled frog leaping algorithm. Journal of Water Resources planning and management. 2003 May;129(3):210-225.

[12] Wang JS, Song JD, Gao J. Rough set-probabilistic neural networks fault diagnosis method of polymerization kettle equipment based on shuffled frog leaping algorithm. Information. 2015 Feb 27;6(1):49-68.