

Solving Benchmark Frequency Assignment Problem of Helsinki Regions Network by a Novel Nature Inspired Algorithm

Avtar Singh Buttar, Ashok Kumar Goel, Shakti Kumar

Abstract—The Frequency Assignment Problem is assignment of frequencies or channels to establish link between base station and mobile transmitter in cellular system. To avoid interference, minimum separation between assigned frequencies is required. This problem is NP-hard. Due to limited availability of spectrum and reuse of same frequencies at different geographical locations, an excellent assignment is to be done, which must satisfy electromagnetic constraints with respect to demand in each cell. This paper presents a novel DGWCHD algorithm for frequency assignment problem in cellular radio networks. The objective is to assign the frequency satisfying electromagnetic constraints for given demand with minimum use of frequency bandwidth. The proposed algorithm is based on real wild animal such as dog's intelligent strategies during chasing and hunting their prey. The proposed algorithm is implemented on benchmark Kunz's test problems, which are practical FAP problems based on area around 25 regions in Helsinki, Finland. The DGWCHD algorithm has been used for call ordering and FEA strategy for assignment. The performance of the proposed novel DGWCHD algorithm has been compared with other nature inspired techniques. The results obtained are very optimistic and encouraging.

Keywords — Chasing & Hunting, Computational intelligence, Dog Group Wild Chase and Hunt Drive (DGWCHD), Combinatorial Optimization, Frequency Assignment Problem Optimization.

I. INTRODUCTION

Over the past years, due to tremendous increase in number of users and their demand for both voice and data services, more and more discrete channels are required to cope with situation. On other hand, available electromagnetic spectrum is limited, the cost of which may be very high. The main problem of planning and operating a mobile communication system is the selection of compatible frequencies to be reused for different channels. The channel plan should utilize the all available frequencies with minimum interference due to co-channel and adjacent channel operation. Various other nets are already present in that area, so the new assignments must be compatible not only with each other but with the old ones as well. The numbers of channels are required to fulfill the demand with minimum span of frequencies. It can be obtained by good assignment. The objective of the work is to utilize minimum span using this computational technique for excellent assignment of channels. There are some good approaches are described in the literature [13]-[27]. This paper is a step forward in this direction. The remainder of the paper is organized as follows: Section II gives a brief description of Dog's and their behavior while Section III describes the algorithm based on chasing &

hunting methodology adopted by dogs. Section IV outlines the implementation of algorithm for solving MSFAP benchmark problems. Section V outlines computational experiments undertaken and the results and comparison with other nature inspired algorithms. Finally, the conclusions and future directions are outlined in Section VI.

II. WILD DOGS AND THEIR BEHAVIOR

A dog is very active, loyal and sensible animal. There are five main sensing organs gifted to dogs: nose (smell), ears (hearing), tongue (bark), eyes (sight) and skin (touch). The first three senses are highly developed, while others are deficient compared with those of humans [1], [2], [3], [4].

Sense of Smell: Olfaction, the act of smelling, is a dog's primary sense. Dog's sense of smell is by far the most acute and is immeasurably better than that of humans. Humans have about 40 million olfactory receptors only, versus 2 billion for a dog. Dogs have an estimated 125-220 million scent cells and can use each nostril independently and thus, are good at distinguishing one odour from another [4], [5], [6]. They can detect one drop of blood in five quarts of water, drugs, explosives, and scents effectively [3].

Sense of hearing: Dogs have very acute sense of hearing and can hear sounds up to a frequency of 60,000 Hz. A dog's ears can move independently from each other, which gives him greater capability to determine direction and cause of sound that helps him to pinpoint rapidly the exact location of a sound [8]. Dogs can also shut off their inner ear in order to filter out distracting sounds. Additionally, the dogs are able to identify a sound's location much faster and can hear sounds up to four times the distance than humans.

Wild Dogs search and hunt for food/prey in small groups, divided into two categories, called chasers and hunters. Chasers are excellent searchers and detectors of food. The prey's position may be static (in sleeping state) or dynamic (moving randomly or in a planned manner to escape). They use their senses like smell & hearing and follow the direction of maximum smell intensity of prey and barking of fellow members of their group for searching and chasing the food-targets/preys. They also use smell to decode scent left by other animals, friend or foe, predator or prey [7],[9]. But, they are not good hunters and cannot run as fast as food-targets to catch and kill them. Hunters use their senses like hearing the barking level/type, direction of sound of chasers, taking position accordingly to hunt the prey. Hunters hear barking sound

of chasers and take their position based on the level of barking intensity moving around outside the hunting field. Hunters then, assess the health of the prey and run to catch/kill them. Therefore, the dogs have divided their jobs as per their physical capabilities.

III. DOG GROUP WILD CHASE AND HUNT DRIVE (DGWCHD) ALGORITHM

The design principle of the algorithm is inspired from chasing and hunting strategies of Wild Dogs [25]. The chasers search and drive the prey away from their home and the hunters make use of barking level of the chasers and health of the prey to judge and catch it.

A. Artificial Hunting field:

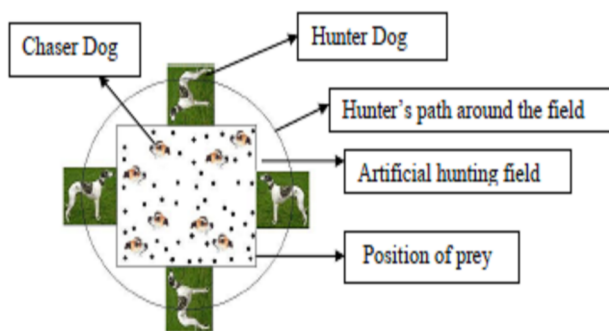


Fig.1. Artificial Hunting Field

As shown in Fig. 1, Artificial Chaser Dogs act as agents who move in the field for searching the food target in different directions at random and chase the prey. The hunters stand outside the field, watch the situation, move and trace the area /path based on movement of Chasers and their respective barking level. When the Hunter is confident that the prey's health is exhausted and can be trapped, it pounces upon the prey and catches it. This process continues until all the prey are hunted or the left over's have run away successfully for survival.

B. The mathematical model of the algorithm:

The hunting field is divided into many sections, each identified by a mark called node as shown in Figure 1.

Artificial Chaser Dog behavior:

The Chasers initially assume that each node is having a prey. The smell of each prey at node j initially taken as S and s_{ij} as smell of prey at node j, is inversely proportional to the distance between j from the Chaser at node i. The barking level of the Chaser when it moves from node i to j is denoted by b_{ij} . Initial value of 'Health' of each prey is assumed as H which decreases as the prey is chased and is exhausted due to running away from the chaser. The health of prey at node j, as seen by the chaser at node i is designated as h_{ij} .

The probability, p_k of selecting j^{th} node by the k^{th} Chaser present at node i, is calculated by the probabilistic function given below:

$$\max_{j=1,n} [p_k(i,j)] = \begin{cases} \frac{[b_{ij}]^\alpha \cdot [s_{ij}]^\beta \cdot [h_{ij}]^\gamma}{\sum_{j=1}^n [b_{ij}]^\alpha \cdot [s_{ij}]^\beta \cdot [h_{ij}]^\gamma} & \text{for } i \neq j \\ 0 & \text{for } i = j \end{cases} \quad \dots (1)$$

Where k, varies from 1 to n_c (n_c is number of Chasers)

s_{ij} , : smell of prey at node j, received by the Chaser at node i

b_{ij} , Cumulative Barking level of chaser in the direction of i and j

h_{ij} , Health of prey at node j as seen from node i

n, total no. of nodes

α , weight-age of barking level

β , weight-age of Smell level

γ , weight-age of Health of prey

While chasing, the prey tries to escape by running away. Consequently, it gets exhausted and its health decreases depending upon the distance it has to run. It is assumed that the maximum distance that the prey runs is equal to that of the chaser. The health of the prey when chaser runs through a distance from node i to j is updated based on equation given below:

$$h_{ij} = h_{ij} - d(i,j) \quad \dots (2)$$

Where, d (i, j) is a function of distance from node i to j.

The barking level of Chasers along a path from node i to j is updated based on equation 3.

$$b_{ij} = b_{ij} * \lambda \quad \dots (3)$$

Where, λ is reduction/fading factor of barking level.

For collective decision barking levels in different directions gives the commutative effect

$$b_{ij} = b_{ij} + \lambda \quad \dots (4)$$

Where,

λ : the ratio of lower bound /assumed optimal distance

D_k to MD_k

D_k : the total distance covered by k^{th} chaser to chase all prey present.

MD_k : the min (D_k) taken as the updated tour length for hunter

nh : Total no. of hunters

Artificial Hunter Dog behavior:

The Hunters stand outside the field, watch the situation, move and trace the area /path based on movement of Chasers and their respective barking level. When the Hunter is confident that the prey's health is exhausted and can be trapped, it pounces upon the prey and catches it.

Hunting choice path array $\eta(i,j)$, for a hunter, is calculated using equation (5)

$$\eta(i,j) = \left(\frac{b(i,j) \cdot (H - h(i,j))}{\max\{\sum_{j=1}^n (b(i,j) \cdot (H - h(i,j)))\}} \right) \quad \dots (5)$$

The Hunter updates the Hunted Path Array from the Hunting choice array using equation (6)

$$ht(i,j) = \begin{cases} 1, & \text{and if } \eta > \eta_0 \\ 0, & \text{if } \eta < \eta_0 \end{cases} \quad \dots (6)$$

where, η_0 is the hunting threshold decision value.

The Value '1' indicates the path is hunted, and '0' indicates otherwise.

The algorithm is repeated for all Hunters till all the preys are hunted and optimal solution is found.


```

/* select first prey i present on node randomly */
/* put i in co */
Loop /* at this level each loop is called a step */
select a prey pi from node ni i := 1, n;
/* using probabilistic function*/
select next prey pj from node nj j = 1, n-1;

$$\max_{j=1,n} [pk(i,j)] = \frac{[b_{ij}]^\alpha \cdot [s_{ij}]^\beta \cdot [h_{ij}]^\gamma \cdot [c_{ij}]^{\beta+\gamma}}{\sum_{j=1}^n [b_{ij}]^\alpha \cdot [s_{ij}]^\beta \cdot [h_{ij}]^\gamma \cdot [c_{ij}]^{\beta+\gamma}}$$

for i j .....(7)
= 0
for i = j
hij = hij - dij ;
hji = hij ;
bij = bij* ;
bji = bij;
/* put j in co */
end;
/*find prey order co with Smin. */
/*prepare result as co and starting FEA technique to find
FA and Smin. */
FA:=Actual frequency assignment to call list (x0)
fmin= Cmax * (Dmax-1)+1;
fmax:=assign frequency to call list (x0)
for
xi:= select first element of call order co(i)
cn:=cell number= co(i)
F1:=first frequency assigned to x1
FA1cn=1
/* next step to assign frequency to next call xj in call order
*/
fk:=another frequency assigned to xj
fk=FA1cn + Cij;
/*check possibility of assignment and find compatible
available frequency*/
/*repeat same step until call order and all assignment
completed*/

```

```

ftr=10*optimal/ Smin ;
for
hij=hij - dij ; i= pi,j= pj;
hji=hij ;
end;
λ =ftr/100;
for
bij=bij + λ;
end
/* Phase 2: hunting by hunters */
begin
for
for

$$\eta(i,j) = \left( \frac{b(i,j) \cdot (H-h(i,j))}{\max\{\sum_{i=1}^n (b(i,j) \cdot (H-h(i,j)))\}} \right); i= p_i, j= p_j;$$

end;
end;
/* prepare hunting array */
begin
ht(i,j) = { 1, if η(i,j) > η0
            0, if η(i,j) < η0
}
/*end of while */;
end;
co;
FA
Smin;

```

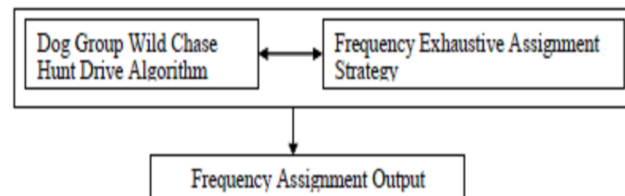


Fig.2. Dog Group Wild Chase Hunt Drive Algorithm with FEA Strategy

Table No. 2: Various parameters of algorithm are taken for the problem with demand vector *D*

Instance Name			+		H	S		η		No. of chasers used nc	No. of hunters used nh
KUNZ4	0.275	2	-5	1	100	100	0.70	1	73/ <i>MD_k</i>	50	1

V. COMPUTATIONAL RESULTS & DISCUSSIONS:

Cell number is mentioned horizontally (*C_i*) and channel number (assigned) vertically. It has been implemented on PC employing Intel Core i5-560M processor with 4GB RAM and using MATLAB version 2012a software and various parameters of algorithm are taken for the problem as shown in Table 2. Only one iteration is required find solution shown in Table 3 of difficult KUNZ4 problem. As shown in Table 3, the frequency assignment of 73 channels (optimum value) is obtained. The proposed algorithm finds the solution of this problem in 166 milliseconds, for call ordering 81 milliseconds and 85 milliseconds for assignment using FEA strategy. So, the proposed algorithm is proved its ability to solve assignment problem and its further usefulness.

VI. CONCLUSION

A novel DGWCHD algorithm, which is based on a computational model inspired by the way real dogs are chasing & hunting their prey, has been described for the MS-FAP. The model chosen to formalize the problem takes the case of multi-interference. The computational results presented are very promising for benchmark considered. With dynamic changes in demand for same compatibility matrix, result can be obtained for dynamic assignment problem also.

Table 3: Simulation Results for Helsinki FAP

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25
2	1	9	1	4	1	15	4	3	18	2	8	12	16	8	1	3	2	9	3	1	12	8	1	4
6	3	17	6	13	5	26	13	12	30	5	10	14	28	10	17	5	4	18	6	4	17	10	3	11
11	5	22	11	15	7	29	16	14	34	7	21	25	37	21	20	13	7	26	11	13	20	14	6	13
20	7	33	20	26	10	44	28	25	40	19	23	27	45	23	31	15	11	29	15	16	28	23	9	16
31	19	39	36	29		54	37		48	24	38	32	54	33	35		19	36	22	25		32	15	18
35	24	46		44			45		56	31	47	41	63	38	39				30	27				21
43	36	55		51			51		64	35	53	49	73	46					34					25
52	42	60		59					72	42	61	57												
62	50	70		67								69	65											
68	58																							
66																								

REFERENCES

- [1] © Owned by Pugs.com “5 Ways Your Dog Senses the World Differently From You”
- [2] www.rcmp-grc.gc.ca Royal Canadian Mounted Police “Dog Senses”
- [3] http://www.aces.edu/counties “The Dog’s Sense of Smell”
- [4] http://www.seefido.com/html/dog_s_5_senses_of_dogs.htm
- [5] http://www.nature.com/nature/journal/v36/n925/abs/036273a0.html
- [6] http://jhered.oxfordjournals.org/cgi/content/full/96/7/812
 SANDRINE TACHER, PASCALE QUIGNON, MAUD RIMBAULT, STEPHANE DREANO, CATHERINE ANDRE, AND FRANCIS GALIBERT “Olfactory Receptor Sequence Polymorphism Within and Between Breeds of Dogs”
- [7] http://www.dog-names.org.uk/hunting-dogs.htm “Hunting Dogs”
- [8] http://ezinearticles.com/?Hunting-Dog-Origins---Tracing-The-Evolution-Of-The-Hunting-Dog
- [9] http://www.ehow.com/how-does_5139011_do-dogs-ears-work
- [10] J. Arthur Zoellner, “Frequency assignment games and strategies,” *IEEE Trans. on Electromagn. Compat.*, Vol. EMC-15, pp. 191-196, Nov. 1973.
- [11] J. A. Zoellner and C. L. Beall, “A breakthrough in spectrum con- serving frequency assignment technology,” *IEEE Trans. Electro-Magn. Compat.*, vol. EMC-19, pp. 313-319, Aug. 1977.
- [12] F. Box, “A Heuristic Technique for Assigning Frequencies to Mo- bile Radio Nets,” *IEEE Trans. Veh. Technol.*, Vol. VT-27, no. 2, pp. 57-64, 1978.
- [13] W. K. Hale, “Frequency assignment: Theory and applications,” *Proc. IEEE*, vol. 68, no. 12, pp. 1497-1514, 1980.
- [14] A. Gamst, Some lower bounds for a class of frequency assignment problems, *IEEE Transactions on Vehicular Technology* 35 (1986), 8-14.
- [15] I.Giortzis L.F.Turner, “Application of mathematical programming to the fixed channel assignment problem in mobile radio networks “*IEE Psoc.-Commun.*, Vol. 144, No. 4, August 1997
- [16] Chiu Y. Ngo, and Victor O. K., IEEE “Fixed Channel Assignment in Cellular Radio Networks Using a Modified Genetic Algorithm”, *IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY*, VOL. 47, NO. 1, FEBRUARY 1998
- [17] J. C. M. Janssen and K. Kilakos. Correspondence-An Optimal Solution to the “Philadelphia” Channel Assignment Problem ,”*IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY*, VOL. 48, NO. 3, MAY 1999
- [18] V. Maniezzo and R. Montemanni, “An Exact Algorithm for the Min-Interference the frequency assignment problem, Deptt. Of computer science University of Bologna Italy web:www.csr.unibino.it/~maniezzo
- [19] V. Maniezzo and A. Carbonaro, “An ANTS heuristic for the frequency assignment problem, *Future Generation Computer Systems* 16 (2000), 927 – 935.
- [20] Zhenya He, Yifeng Zhang , Chengjian Wei and Jun Wang “Multistage Self –Organising Algorithm Combined Transiently Chaotic Neural Network For Cellular Channel Assignment” *IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY*, VOL. 51, NO. 6, Nov., 2002
- [21] Jaime Abril, Francesc Comellas, Alejandro Cortés, Javier Ozón, and Miguel Vaquer”A Multiagent System for Frequency Assignment in Cellular Radio Networks”, *IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY*, VOL. 49, NO. 5, SEPTEMBER 2000
- [22] Ralf Borndorfer, Andreas Eisenblatter ,Martin Grottschel, Alexander martin ,”The Orientation Model for Frequency Assignment Problems”, Technical report TR 98-01 April, 1998.
- [23] KAREN I. AARDAL STAN P.M. VAN HOESEL ARIE M.C.A. KOSTER CARLO MANNINO ANTONIO SASSANO ,”Models and Solution Techniques for Frequency Assignment Problems”, ZIB-Report 01-40 (December 2001)
- [24] Roberto Montemanni, Derek H. Smith and Stuart M. Allen, “An ANTS Algorithm for the Minimum-Span Frequency Assignment Problem with Multiple Interference” *IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY*, VOL. 51, NO. 5, Sept., 2002
- [25] Avtar Singh Buttar, Ashok Kumar Goel, Shakti Kumar Patent Title: Wild Intelligence: A NOVEL INTELLIGENCE AS DOG GROUP WILD CHASE & HUNT DRIVE (DGCHD), Application No.:DEL/ 1965/2008 *Indian Patent Office Journal*, issue No.14/2010, pp.7362, April, 2010
- [26] Marcos A. C. Lima, Aluizio F. R. Araújo, and Amílcar C. César, “Adaptive Genetic Algorithms for Dynamic Channel Assignment in Mobile Cellular Communication Systems,” *IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY*, VOL. 56, NO. 5, SEPTEMBER 2007
- [27] Lhassane Idoumghar and Rene Schott, “Two Distributed Algorithms for the Frequency Assignment Problem in the Field of Radio broadcasting”, *IEEE TRANSACTIONS ON BROADCASTING*, VOL. 55, NO. 2, JUNE 2009

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