Studies on Various Maximal Covering Location Problems using Genetic and ABC Algorithms

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Acknowledgement

I am deeply grateful to my supervisors:

Prof. Priya Ranjan Sinha Mahapatra, Department of CSE, University of Kalyani

Dr. Soumen Atta, School of Engineering and Management, University of Nova Gorica.

Their guidance, support, and motivation have been invaluable in shaping my research and propelling me to new achievements.

I also extend my thanks to the **CSE Department** at the **University of Kalyani** for granting me access to essential laboratory resources that played a vital role in the successful completion of this project. The unwavering support and encouragement from the faculty and staff in the department have been a constant source of inspiration.

Lastly, I want to express my heartfelt appreciation to **my family and friends** who have been with me throughout my academic journey. Their love, encouragement, and unwavering support have been the solid foundation of my accomplishments.

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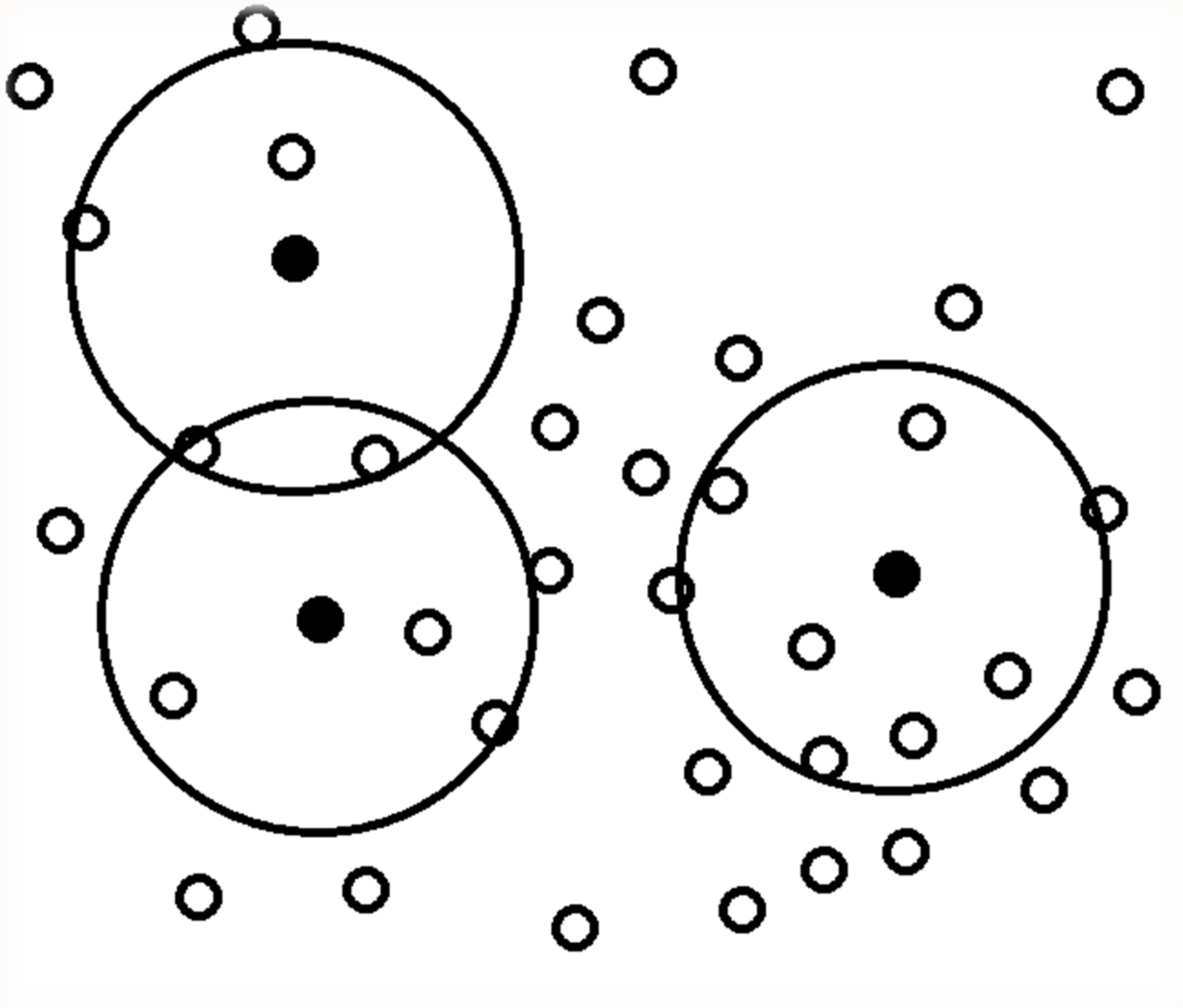
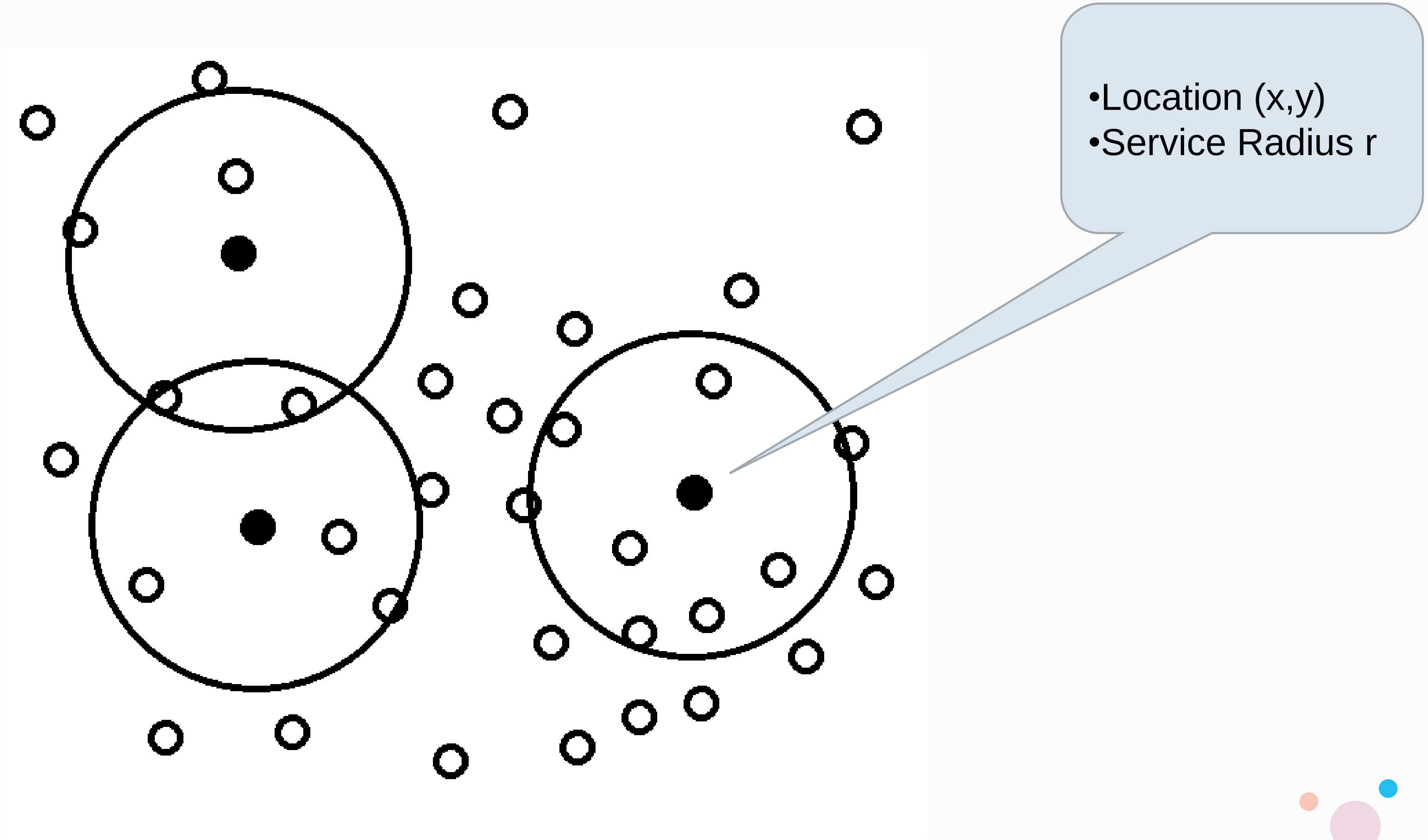
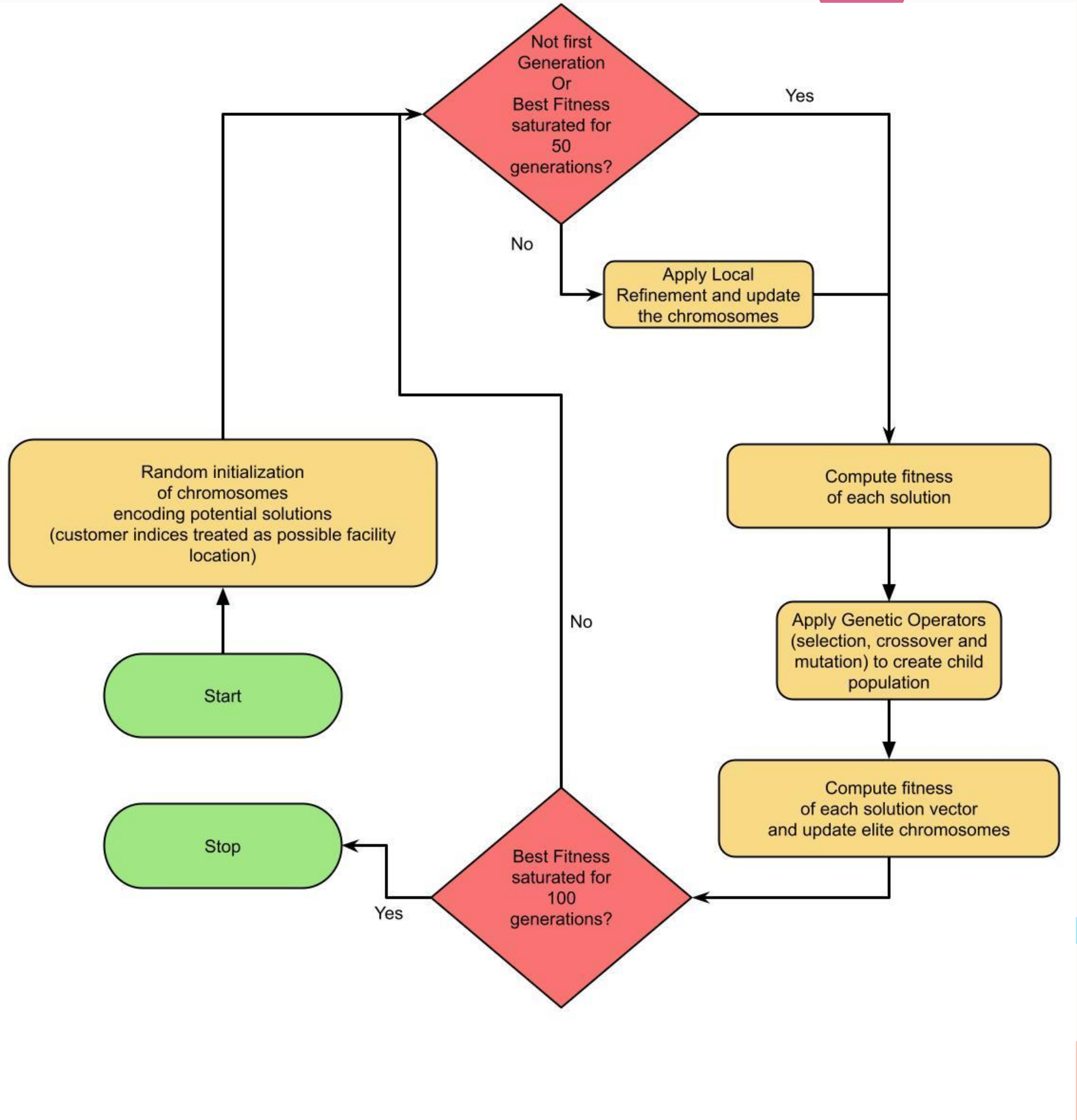
Let us understand Basic MCLP[3]



Let us understand Basic MCLP[3]



Implementation of MCLP using GA with local refinement[1]



Experimental Results of Implementation

Table 1.1: Experimental Results with GA with refinement-based solving for SJC324 MCLP

n	p	S	Cov.(%)	Gap (%)	Time(s)
324	1	800	**44.94**	**0**	1.64
324	2	800	**72.33**	**0**	2.47
324	3	800	**95.49**	**0**	3.43
324	4	800	**99.62**	**0**	5.66
324	5	800	**100**	**0**	2.95
324	1	1200	**81.73**	**0**	4.62
324	2	1200	**95.08**	**0**	4.18
324	3	1200	**100**	**0**	3.17
324	1	1600	**99.76**	**0**	5.65
324	2	1600	**100**	**0**	3.77

Table 1.2: Experimental Results with GA with refinement-based solving for SJC402 MCLP

n	p	S	Cov.(%)	Gap (%)	Time(s)
402	1	800	**41.01**	**0**	1.58
402	2	800	**70.94**	**0**	2.71
402	3	800	**91.9**	**0**	4.65
402	4	800	97.85	0.11	5.51
402	5	800	**99.91**	**0**	4.89
402	6	800	**100**	**0**	4.03
402	1	1200	**66.36**	**0**	4.16
402	2	1200	**92.79**	**0**	4.95
402	3	1200	**100**	**0**	4.53
402	1	1600	**96.58**	**0**	7.37
402	2	1600	**100**	**0**	5.53

Table 1.3: Experimental Results with GA with refinement-based solving for SJC500 MCLP

n	p	S	Cov.(%)	Gap (%)	Time(s)
500	1	800	**40.31**	**0**	1.84
500	2	800	**63.2**	**0**	3.41
500	3	800	**79.82**	**0**	4.81
500	4	800	90.18	0.11	8.03
500	5	800	**95.7**	**0**	15.83
500	6	800	**99.08**	**0**	17.20
500	7	800	**99.92**	**0**	11.87
500	8	800	99.97	0.03	5.426376
500	1	1200	**54.43**	**0**	3.20
500	2	1200	**91.69**	**0**	6.52
500	3	1200	**98.41**	**0**	7.05
500	1	1600	**75.12**	**0**	6.40
500	2	1600	**99.8**	**0**	7.74
500	3	1600	**100**	**0**	6.14

Table 1.4: Experimental Results with GA with refinement-based solving for SJC708 MCLP

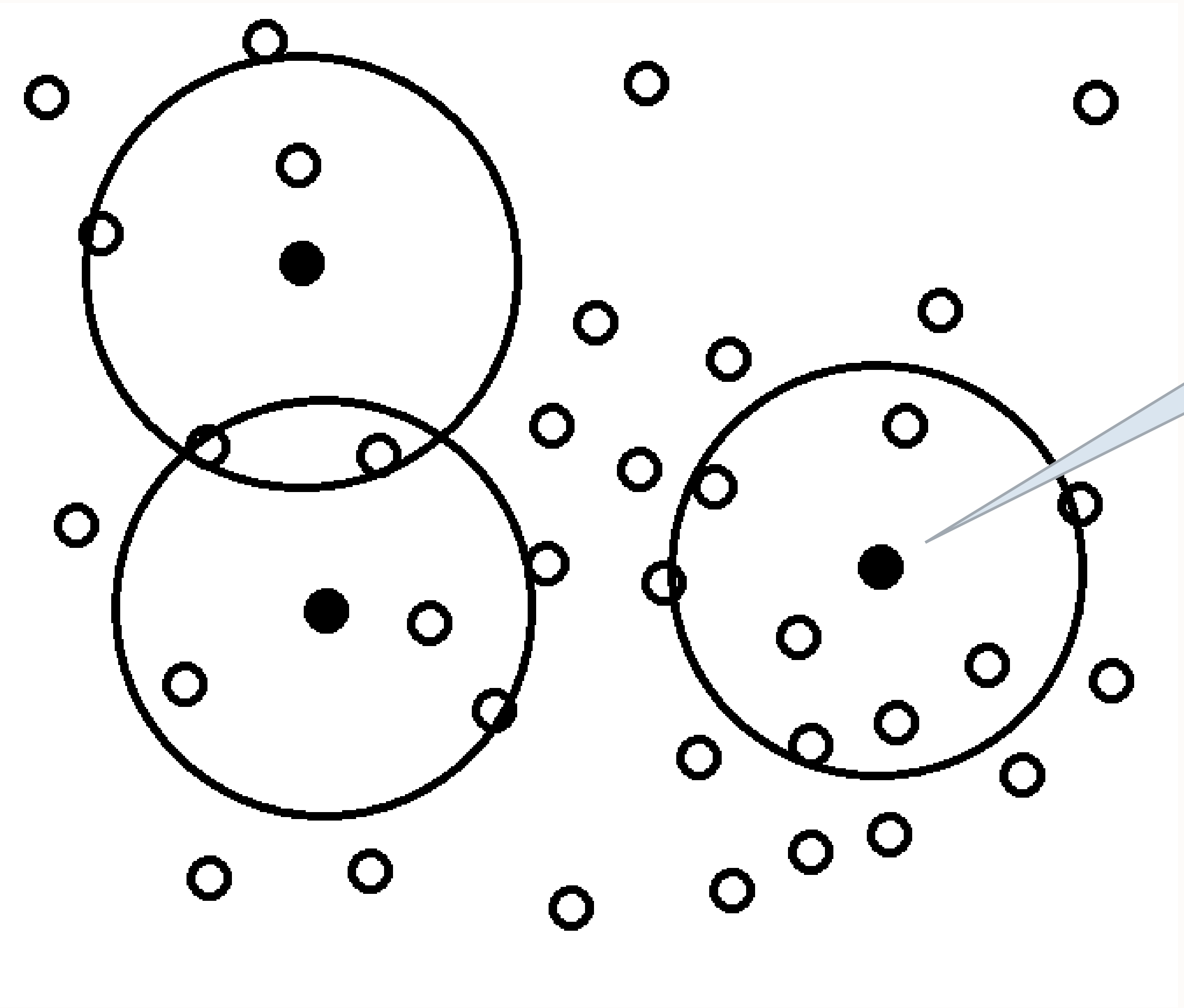
n	p	S	Cov.(%)	Gap (%)	Time(s)
708	1	800	**34.69**	**0**	2.58
708	2	800	**55**	**0**	4.65
708	3	800	**71.4**	**0**	6.29
708	4	800	**84.07**	**0**	17.57
708	5	800	**88.81**	**0**	35.01
708	6	800	92.69	0.33	30.68
708	7	800	94.75	0.95	24.42
708	8	800	**97.83**	**0**	26.25
708	9	800	98.5	0.6	14.48
708	10	800	98.95	1.4	20.93
708	11	800	**100**	**0**	14.828
708	1	1200	**48**	**0**	4.52
708	2	1200	**84.23**	**0**	9.10
708	3	1200	**92.68**	**0**	12.58
708	4	1200	**98.73**	**0**	27.78
708	5	1200	99.66	0.13	20.04
708	6	1200	**100**	**0**	10.31
708	1	1600	**69.56**	**0**	9.41
708	2	1600	**96.59**	**0**	18.10
708	3	1600	98.59	0.15	10.36
708	4	1600	**100**	**0**	8.66

Experimental Results of Implementation

Table 1.5: Experimental Results with GA with refinement-based solving for SJC818 MCLP

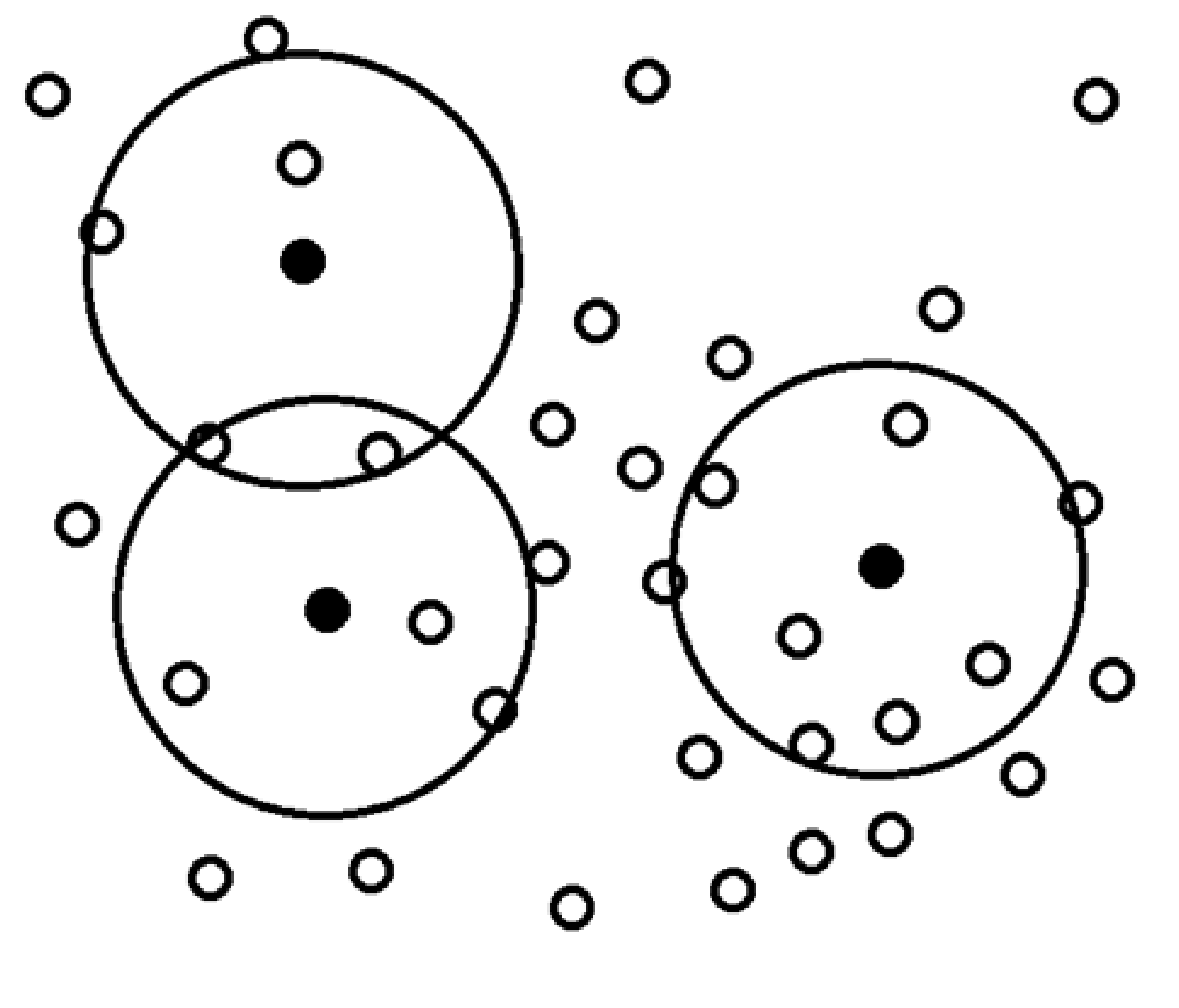
n	p	S	Cov. (%)	Gap (%)	Time (s)
818	1	800	**28.77**	**0**	2.67
818	2	800	**45.62**	**0**	10.84
818	3	800	**60.02**	**0**	15.53
818	4	800	73.10	0.36	7.64
818	5	800	83.21	0.89	21.21
818	6	800	87.49	1.33	24.52
818	7	800	90.19	2.15	24.96
818	8	800	94.06	1.29	35.48
818	9	800	96.59	0.77	37.87
818	10	800	97.67	0.88	37.47
818	11	800	98.93	0.81	29.14
818	12	800	99.14	0.67	26.68
818	13	800	**99.98**	**0**	34.59
818	14	800	**100**	**0**	15.56
818	1	1200	**39.81**	**0**	7.98
818	2	1200	**69.56**	**0**	16.68
818	3	1200	**86.43**	**0**	23
818	4	1200	92.46	0.21	27.09
818	5	1200	97.35	0.40	26.63
818	6	1200	99.59	0.30	29.47
818	7	1200	99.96	0.04	11.74
818	1	1600	**57.69**	**0**	10.12
818	2	1600	**84.5**	**0**	15.12
818	3	1600	**94.87**	**0**	21.76
818	4	1600	**98.95**	**0**	22.39
818	5	1600	**100**	**0**	10.91

Recall: MCLP[3]



- Location (x,y)
- Service Radius r

PMCLAP[12]: MCLP with minimum service quality



- Clients will arrive to a facility according to a Poisson distribution with parameter rate μ.
- The parameter α defines the minimum probability of
- at most a queue with b clients, or;
- a waiting time of Ꞇ minutes.

Mathematical Formulation [14]

To model the PMCLAP, we define two sets of binary variables: one of location and the other for one for allocation decisions. Variables y_j are equal to one if and only if location $j \in N$ is opened, and variables x_{ij} are equal to one if and only if the demand of node i is associated with facility j, $i,j \in N$. The problem can be formulated as follows:

$$maximize \sum_{i \in N} \sum_{j \in N_i} d_i x_{ij} \quad (1)$$

subject to

$$\sum_{j \in N_i} x_{ij} \leq 1, \quad i \in N \quad (2)$$

$$\sum_{i \in N} y_j = p \quad (3)$$

$$x_{ij} \leq y_j, \quad i \in N, \ j \in N \quad (4)$$

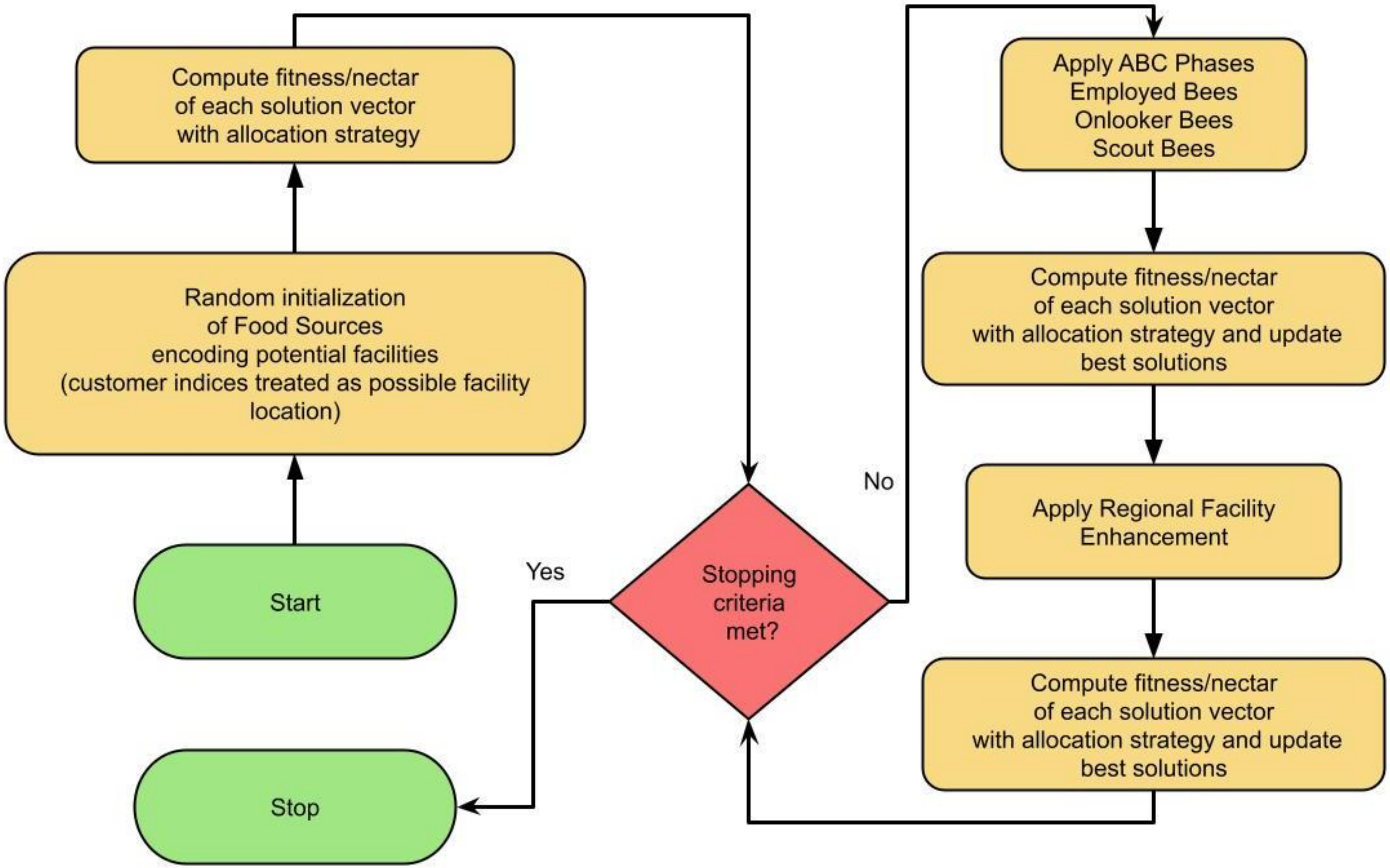
$$\sum_{i \in N} f_i x_{ij} \leq \mu \sqrt[b+2]{1-\alpha} \quad j \in N \quad (5)$$

$$\sum_{i \in N} f_i x_{ij} \leq \mu + \frac{1}{\tau} \ln(1-\alpha), \quad j \in N \quad (6)$$

$$y_j, x_{ij} \in \{0,1\}, i \in N, j \in N \quad (7)$$

Proposed Experimental Methodology

Solving using Artificial Bee Colony Algorithm with Regional Facility Enhancement


Compute fitness/nectar
of each solution vector
with allocation strategy
Random initialization
of Food Sources
encoding potential facilities
(customer indices treated as possible facility
location)
Start
Stop
Yes
Stopping
criteria
met?
No
Apply ABC Phases
Employed Bees
Onlooker Bees
Scout Bees
Compute fitness/nectar
of each solution vector
with allocation strategy and update
best solutions
Apply Regional Facility
Enhancement
Compute fitness/nectar
of each solution vector
with allocation strategy and update
best solutions

Allocation Strategy

GET-LEAST-CONGESTED-FACILITY	For each customer choose the least congested feasible facility
GET-MAX-WEIGHTED-CUSTOMER	For each facility choose the feasible customer having max (demand/distance)
GET-RANDOM-FACILITY	For each customer allocate a feasible facility randomly

Initial 50 epochs, best of 3 strategies is used

Remaining, roulette wheel selection is used.

Proposed Regional Facility Enhancement

- For each facility in a solution vector of colony
  - N% nearest neighbors of the facility are taken
  - Randomly one facility is chosen and inserted into solution vector
  - If nectar(new solution vector) >= nectar(existing solution vector)
    - Update: existing solution vector <- new solution vector
  - Repeat for all remaining facilities in the updated or unchanged solution vector

Software used for implementation

- Matlab™ R2021a
  - Machine Configuration-> Intel i5™ 7th Gen, 8GB Ram
  - All of the instances consumed less than 500 MB of Ram

Experimental Results

	CPLEX		MS Heuristic [12]		GRASP [6]			CS [4]			ANLS [14]			Proposed ABC with Enhancement				
Instance	Best	Time(s)	Best	Time(s)	Best	Average	Time(s)	Best	Average	Time(s)	Best	Average	Time(s)	Best	Average	Std. Dev	Gap (%)	Time(s)
30_2_0_0_85	**3700**	0	**3700**	0.000	**3700**	3700	0.007	**3700**	3700	0.009	**3700**	3700	12.333	**3700**	3700	0	**0**	2.28
30_2_0_1_85	**5100**	0	4630	0.000	5090	5090	0.016	5090	5090	0.018	**5100**	5100	9.000	5090	5090	0	0.19	2.51
30_2_0_2_85	**5210**	0	4780	0.000	**5210**	5210	0.015	**5210**	5210	0.016	**5210**	5210	4.667	**5210**	5210	0	**0**	2.63
30_2_0_2_95	**4520**	0	4470	0.000	**4520**	4520	0.013	**4520**	4520	0.015	**4520**	4520	11.333	**4520**	4520	0	**0**	2.85
30_3_0_0_85	**5390**	0	5210	0.000	**5390**	5390	0.025	**5390**	5390	0.025	**5390**	5390	5.000	**5390**	5390	0	**0**	3.17
30_3_0_1_85	**5390**	0	5210	0.000	**5390**	5390	0.024	**5390**	5390	0.024	**5390**	5390	3.000	**5390**	5390	0	**0**	3.30
30_3_0_1_95	**5270**	6	5080	0.000	5240	5240	0.024	5240	5240	0.024	**5270**	5270	44.667	5260	5244	8	0.18	3.15
30_3_0_2_85	**5390**	1	5210	0.000	**5390**	5390	0.022	**5390**	5390	0.023	**5390**	5390	3.667	**5390**	5390	0	**0**	3.29
30_3_0_2_95	**5390**	0	5230	0.000	**5390**	5390	0.023	**5390**	5390	0.027	**5390**	5390	3.667	**5390**	5390	0	**0**	3.25
30_3_1_49_90	**2160**	0	**2160**	0.000	**2160**	2160	0.007	**2160**	2160	0.009	**2160**	2160	13.333	**2160**	2160	0	**0**	3.56
30_4_0_1_95	**5390**	0	5260	0.000	**5390**	5390	0.022	**5390**	5390	0.026	**5390**	5390	8.333	**5390**	5390	0	**0**	3.96
30_4_1_42_85	**4600**	0	4550	0.000	**4600**	4600	0.016	**4600**	4600	0.022	**4600**	4600	105.667	**4600**	4600	0	**0**	5.45
30_4_1_48_90	**1920**	0	1890	0.000	**1920**	1920	0.011	**1920**	1920	0.014	**1920**	1920	17.333	**1920**	1920	0	**0**	5.70
30_4_1_49_90	**2880**	0	2870	0.000	**2880**	2880	0.008	**2880**	2880	0.013	**2880**	2880	15.000	**2880**	2871	3	**0**	3.28
30_5_0_0_95	**5330**	13	5210	0.000	**5330**	5312.8	0.032	**5330**	5317.6	0.041	**5330**	5330	288.667	**5330**	5314	22.44	**0**	4.62
30_5_1_40_85	**3050**	93	2910	0.000	**3050**	3033.2	0.016	**3050**	3033.2	0.021	**3050**	3050	234.000	3000	3000	0	1.63	3.95
30_5_1_42_85	**5390**	1	5210	0.000	**5390**	5390	0.027	**5390**	5390	0.035	**5390**	5390	15.000	**5390**	5390	0	**0**	5.75
30_5_1_48_90	**2400**	1	2280	0.000	**2400**	2398.8	0.013	**2400**	2398.8	0.019	**2400**	2400	26.667	2390	2390	0	0.41	4.45
30_5_1_50_90	**4700**	1	4670	0.000	**4700**	4700	0.018	**4700**	4700	0.028	**4700**	4700	42.667	**4700**	4698	4	**0**	4.82
30_6_0_0_95	**5410**	1	5390	0.000	5390	5390	0.029	**5410**	5391	0.037	**5410**	5410	62.333	**5410**	5391.33	4.98	**0**	5.47
30_6_1_40_85	**3610**	10803	3480	0.000	**3610**	3606.8	0.021	**3610**	3608.8	0.031	**3610**	3610	514.000	**3610**	3604	8	**0**	5.83
30_6_1_41_85	**5330**	10802	5120	0.000	5270	5270.0	0.028	**5330**	5286.4	0.038	**5330**	5330	322.333	**5330**	5320	8.94	**0**	5.78
30_6_1_50_90	**5390**	1	5060	0.000	**5390**	5390	0.027	**5390**	5390.0	0.038	**5390**	5390	31.667	**5390**	5390	0	**0**	7
30_7_1_40_85	**4060**	1	3860	0.000	**4060**	4060	0.028	**4060**	4060	0.039	**4060**	4060	301.00	**4060**	4060	0	**0**	6.41
30_7_1_41_85	**5410**	1	5300	0.000	5390	5390	0.023	5390	5390	0.035	**5410**	5410	61.333	5390	5390	0	0.37	6.61
30_8_1_41_85	**5470**	0	5390	0.000	**5470**	5470	0.019	**5470**	5470	0.032	**5470**	5470	8.333	**5470**	5470	0	**0**	8.05
Average	**4533.1**	**835.577**	**4389.6**	**0.000**	**4527.7**	**4526.2**	**0.02**	**4530.8**	**4527.1**	**0.025**	**4533.1**	**4533.1**	**83.269**	**4529.2**	**4526.24**	**2.28**	**0.10**	**4.5**

Experimental Results

	CPLEX		MS Heuristic [12]		GRASP [6]			CS [4]			ANLS [14]			Proposed ABC with Enhancement				
Instance	Best	Time(s)	Best	Time(s)	Best	Average	Time(s)	Best	Average	Time(s)	Best	Average	Time(s)	Best	Average	Std. Dev	Gap (%)	Time(s)
324_10_0_0_85	**37180**	13	37081	0.220	37157	37155.8	2.24	37173	37163.2	3.460	**37180**	37180	1255.333	37172	37161.60	5.49	0.02	38.28
324_10_0_0_95	**21460**	9	21386	0.140	21446	21441.2	2.05	21455	21447.2	3.160	**21460**	21460	865.667	21456	21450.60	3.97	0.01	46.60
324_10_0_1_85	**51000**	22	50750	0.200	50948	50946.3	2.30	50948	50946.3	3.410	**51000**	51000	1435.000	50944	50919.50	22.57	0.10	44.64
324_10_0_1_95	**35360**	14	35250	0.160	35339	35336.5	2.06	35359	35354.6	3.170	**35360**	35360	857.000	35357	35355.90	1.70	0.08	36.35
324_10_0_2_85	**59740**	22	59598	0.200	59693	59688.5	2.24	59693	59688.5	3.330	**59740**	59740	987.667	59666	59644.50	12.31	0.12	35.80
324_10_0_2_95	**45390**	9	45300	0.200	45341	45334.6	2.01	45374	45354.6	3.100	**45390**	45390	1292.000	45366	45359.80	3.31	0.05	49.25
324_10_1_40_85	**27700**	14	27283	0.170	27670	27666.6	2.18	27698	27692.1	3.370	**27700**	27700	1406.333	27692	27687.30	3.95	0.02	38.51
324_10_1_41_85	**29360**	6	29288	0.140	29658	29656.1	2.24	29351	29341.9	3.520	**29360**	29360	1182.667	29350	29346.60	2.57	0.03	37.78
324_10_1_42_85	**30950**	11	30902	0.170	30928	30920.8	2.21	30948	30943.3	3.330	**30950**	30950	1034.667	30947	30944.10	3.20	0.009	39.62
324_10_1_48_90	**26920**	15	26885	0.140	26899	26896.6	2.18	26917	26910.6	3.500	**26920**	26920	1492.667	26914	26907.10	4.34	0.02	49.02
324_10_1_49_90	**28330**	22	28206	0.250	28295	28285.0	2.24	28318	28310.3	3.430	**28330**	28330	1747.000	28317	28310.80	4.21	0.01	36.58
324_10_1_50_90	**29680**	6	29638	0.220	29658	29656.1	2.24	29672	29665.5	3.360	**29680**	29680.0	1127.33	29669	29665.30	2.75	0.03	48.54
324_20_0_0_85	**74360**	198	73981	0.830	74165	74106.0	4.80	74165	74106.7	9.710	**74360**	74357.7	6191.667	74188	74039.10	89.77	0.23	96.91
324_20_0_0_95	**42920**	22	42714	0.730	42813	42792.2	4.24	42840	42804.9	9.370	**42920**	42919.7	3936.333	42852	42835.50	12.04	0.15	77.06
324_20_0_1_85	**102000**	612	100628	1.020	101374	101177.4	4.88	101374	101177.4	9.070	101978	101974	7212.667	101045	100600.10	273.21	0.93	105.92
324_20_0_1_95	**70720**	55	70368	0.740	70561	70529.8	4.43	70656	70628.2	9.060	**70720**	70720	4417.333	70762	70641.20	11.26	0.05	102.59
324_20_0_2_85	**119740**	10804	118451	0.770	118771	118613.6	4.86	118771	118613.6	8.990	119455	119447.3	6388.000	118193	117927.40	169.44	1.29	97.45
324_20_0_2_95	**90780**	74	90424	0.810	90550	90518.9	4.64	90556	90521.2	9.400	**90780**	90780	6667.333	90604	90529.90	50.54	0.19	68.40
324_20_1_40_85	**55400**	52	55006	0.840	55193	55147.4	4.63	55306	55226.7	9.650	55396	55398.3	5488.667	55303	55249.50	41.96	0.17	72.03
324_20_1_41_85	**58720**	85	58577	1.020	58602	58582.6	4.72	58604	58583.4	10.330	**58720**	58720	7417.667	58626	58515.40	81.26	0.16	109.16
324_20_1_42_85	**61900**	35	61637	0.880	61746	61715.1	4.68	61847	61822.6	9.740	**61900**	61900	3561.333	61849	61831.30	14.10	0.01	102.38
324_20_1_48_90	**53840**	49	53377	0.630	53647	53607.5	4.54	53793	53689.5	9.820	53839	53838.7	5912.667	53760	53711.90	36.52	0.14	88.30
324_20_1_49_90	**56660**	167	56180	1.340	56321	56254.3	4.59	56532	56429.9	9.550	56655	56655	7130.667	56533	56466.70	63.78	0.22	88.03
324_20_1_50_90	**59360**	56	59119	0.940	59253	59237.0	4.74	59285	59242.6	10.080	**59360**	59360	5551.333	59287	59262.50	18.91	0.12	102.29
Average	**52883.3**	**515.5**	**52595.8**	**0.532**	**52751.1**	**52719.4**	**3.41**	**52776.5**	**52736.0**	**6.455**	**52881.5**	**52880.9**	**3523.292**	**52,743.8**	**52681.8**	**38.8**	**0.17**	**67.14**

Experimental Results

	CPLEX		MS Heuristic [12]		GRASP [6]			CS [4]			ANLS [14]			Proposed ABC with Enhancement				
Instance	Best	Time(s)	Best	Time(s)	Best	Average	Time(s)	Best	Average	Time(s)	Best	Average	Time(s)	Best	Average	Std. Dev	Gap (%)	Time(s)
818_10_0_0_95	**21460**	557	21429	4.94	21459	21458.3	6.30	**21460**	21459.9	11.23	**21460**	21460	6818	**21460**	21460	0	**0**	60.37
818_10_0_1_95	**35360**	657	35339	13.05	**35360**	35360	6.65	**35360**	35360	11.54	**35360**	35360	10407	**35360**	35359	1.54	**0**	61.82
818_10_0_2_95	**45390**	648	45375	12.09	45389	45388.2	6.97	**45390**	45390	12.17	**45390**	45390	7400	**45390**	45389.40	0.80	**0**	62.96
818_10_1_48_90	**26290**	586	26907	11.38	26899	26896.6	2.18	**26920**	26920	11.320	**26920**	26920	8212	**26920**	26919.60	1.20	**0**	103.70
818_10_1_49_90	**28330**	659	28309	8.630	28295	28285	2.24	**28330**	28330	12.230	**28330**	28330	8052.6667	**28330**	28328.10	2.25	**0**	83.17
818_10_1_50_90	**29680**	682	29661	18.280	29658	29656.1	2.24	**29680**	29680	11.330	**29680**	29680	9078.333	**29680**	29679.90	0.30	**0**	83.07
818_20_0_0_85	**74360**	785	74313	75.05	74353	74352.1	16.27	**74360**	74359.8	66.81	**74360**	74360	17183.667	**74360**	74355	3.92	**0**	102.90
818_20_0_0_95	**42920**	562	42793	25.67	42903	42900	14.51	**42920**	42918.9	54.84	**42920**	42920	9890.333	42918	42917.10	0.53	0.004	96.32
818_20_0_1_85	**102000**	1491	101933	76.06	101996	101991.9	19.24	**102000**	101998.9	67.36	**102000**	102000	16602	**102000**	101990.80	10.21	**0**	103.511
818_20_0_1_95	**70720**	610	70644	37.03	70717	70715.1	16.90	**70720**	70719.2	62.91	**70720**	70720	16880.667	**70720**	70717.80	1.77	**0**	96.18
818_20_0_2_85	**119480**	1579	119397	105.48	119468	119466	21.26	**119480**	119477.6	74.36	**119480**	119480	19074.667	**119480**	119472.20	13.15	**0**	104.08
818_20_0_2_95	**90780**	841	90730	75.19	90772	90769.5	19.18	**90780**	90779.6	66.80	**90780**	90780	14622.667	**90780**	90774.20	4.48	**0**	102.11
818_20_1_40_85	**55400**	833	55325	66.110	55193	55147.4	4.63	**55400**	55399	61.040	**55400**	55400	15044.333	**55400**	55395.30	8.92	**0**	163.10
818_20_1_41_85	**58720**	641	58637	69.630	NA	NA	NA	**58720**	58719.9	57.310	**58720**	58720	14384	**58720**	58715.90	7.35	**0**	169.17
818_20_1_42_85	**61900**	929	61814	71.810	NA	NA	NA	**61900**	61898.8	58.710	**61900**	61900	14487	61899	61886	17.64	0.001	157.11
818_20_1_48_90	**53840**	640	56602	34.340	NA	NA	NA	**53840**	53839.6	59.560	**53840**	53840	13808.667	**53840**	53836.30	4.51	**0**	155.97
818_20_1_49_90	**56660**	948	56602	34.340	NA	NA	NA	**56660**	56660	67.420	**56660**	56660	13008.333	**56660**	56655.10	4.84	**0**	166.31
818_20_1_50_90	**59360**	877	59269	39.840	NA	NA	NA	**59360**	59359.9	58.480	**59360**	59360	14568.667	**59360**	59357	3.76	**0**	161.33
818_50_0_0_85	**185900**	2956	185426	756.72	1857791	185755.8	50.62	185880	185775.6	364.20	185637	185587.7	24094.33	185855	185801	59.16	0.02	339.63
818_50_0_1_85	**255000**	6332	254509	730.20	254860	254836.6	58.37	254985	254905.0	387.37	254996	254987.3	23978	254934	254868.50	61.11	0.02	360.95
818_50_0_2_85	**298700**	4435	298217	757.73	2988547	298511.2	63.58	298582	298517.6	392.29	298692	298648.3	23978	298548	298344.50	114.98	0.05	390.01
818_50_1_48_90	**134600**	785	134088	596.110	NA	NA	NA	134598	134561.6	335.000	134597	134593.3	24094.333	134592	134578.70	10.24	0.05	481.34
818_50_1_49_90	**141650**	1719	141281	571.170	NA	NA	NA	141586	141532.8	356.800	**141650**	141606.7	24425	141614	141597	13.09	0.02	506.78
818_50_1_50_90	**148400**	1946	147931	667.670	NA	NA	NA	148383	148321.9	337.400	148397	148378	25031.667	148366	148327.30	26.88	0.02	510.95
Average	**91563.8**	**1363.417**	**91402.4**	**201.941**	**NA**	**NA**	**NA**	**91553.9**	**91536.9**	**124.937**	**91552**	**91545.1**	**15659.125**	**91549.42**	**91530.24**	**15.52**	**0.007**	**192.61**

Conclusion

Promising results for the 30 node data-set and 818 node data-set

However, for 324-node dataset the benchmark results were missed by a small margin.

Overall achieves the optimal benchmark results of CPLEX in 50% of time, with an average computational time of 85.83 seconds

The quality of the heuristic solutions depends largely on the customer allocation strategy

Future research will focus on developing improved allocation strategies to enhance the performance of the heuristic method.

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Thank you!

If you have any queries feel free to ask