

OPTIMAL DATA REPLACEMENT TECHNIQUE FOR COOPERATIVE CACHING IN MANET

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Abstract

A cooperative caching approach improves data accessibility and reduces query latency in Mobile Ad hoc Network (MANET). Maintaining the cache is challenging issue in large MANET due to mobility, cache size and power. The previous research works on caching primarily have dealt with LRU, LFU and LRU-MIN cache replacement algorithms that offered low query latency and greater data accessibility in sparse MANET. This paper proposes Memetic Algorithm (MA) to locate the better replaceable data based on neighbours interest and fitness value of cached data to store the newly arrived data. This work also elects ideal CH using Meta heuristic search Ant Colony Optimization algorithm. The simulation results shown that proposed algorithm reduces the latency, control overhead and increases the packet delivery rate than existing approach by increasing nodes and speed respectively.

Keywords:

Data Replacement, Clustering, Cooperative Caching, Optimization

1. INTRODUCTION

Massive growth of wireless communication technologies enhances research interest in MANETs. An earlier research on ad hoc networks focused on developing routing protocols that improved one-hop and/or multi-hop connectivity between mobile nodes [1]. Though routing is an essential constraint, data availability is also major requirement factor for better accessibility in MANET [2].

Caching is an attractive technique to improve data availability that enhances Quality of Service (QoS) at clients i.e., reduces jitter, latency, packet loss, data server/source workload. Additionally, bandwidth consumption reduction causes greatly increased mobile client's battery life [3]. Cooperative caching provided better solution to enhance the data availability problem that allowed sharing and coordination among mobile nodes [4]. Data availability is limited since frequent node movement, limited storage space and frequent disconnections. By caching frequently accessed data in ad hoc networks, data accessibility, QoS and availability are improved. The caching technique meant for wired network may not be applicable to the MANET since mobility and resource constraints. A good cache management should address these issues for MANET [5]:

- i. An efficient cache discovery algorithm should either discover or deliver requested data to nodes and make a decision that data should be cached for future use. Cooperative caching decides not only based on the caching node but also on the other nodes aspiration.

- ii. Better data replacement algorithm is needed to replace cached data when cache space is not sufficient to cache newly arrived data.
- iii. A cache consistency algorithm should ensure that cached data items are updated.

Cache management consists of cache admission control, cache consistency maintenance and cache replacement. Least Frequently Used (LFU) maintains a reference count for each cached data. Whenever there is a cache hit, the reference count of the data has been incremented by one. In case of a cache miss and insufficient free space in the cache, the data with lowest reference count is replaced. Cache consistency strategy keeps cached data items synchronized with original data at data source. Least recently used information with minimal page replacements LRU-MIN maintained a sorted data list at the hash table based on least recently used information i.e. based on time when data was last used [6].

When cache replaces a data, it searches from hash tail and evicts data items that have equal or greater size than newly arrived data items. Cache admission control makes a node to cache all received data until cache space is full. Then received data are not cached, if received data copy is inside the cluster. When a new data arrives to node during cache space is full then cache replacement algorithm required to locate one or more replaceable obsolete cached data in the cache [7].

Least Recently Used (LRU) evicts data based on least recently used information [8], [9]. LRU maintains a hash table about past accessed data in the clusters. The table head includes most recently used information and the tail has least recently used information. When a new data item comes to the cache, it is added to the table's tail. When a cache hit occurs, requested data item's access time is updated and moved to list head. When cache is full, it removes list's tail element. This has not considered the neighbours interest on cached data.

A novel Proximity Regions for Caching is presented to support scalable data retrieval in large scale mobile peer to peer networks [10]. It considered data popularity, data size and region-distance during replacement to optimize peers cache content. It used a hybrid push pull mechanism to ensure data consistency among network replicas. But it has not dealt with replacement based on neighbour user's interest. A hybrid prefetching caching scheme forwarded data request hop by hop to data centre, that in turn reverts the requested data [11].

This proposed approach fetched the data in advance based on data type required by the nodes after ensured similar data copy is

not retained by them. This scheme reduced overheads and improved the latency in sparse network. Hence it has not opted for dense network.

This work proposes an optimal technique to enhance the data replacement using MA [12], [13], that also addresses Cluster Head (CH) selection using Ant Colony Optimization (ACO) [14], [15] that act as a local server and ensures the consistency through caching policy.

2. METHODOLOGY

The network topology is divided into non overlapping clusters. The proposed model added the cache utilization constraint in CH selection using an ACO algorithm that includes artificial ants. Location chosen by most ants with high pheromone acts as CH and is the ideal mid-path of ants to reach food and to store it temporarily (data cache in this case). But there could be other nodes that may be more ideal from a caching issue perspective. After selection of best CH, a local search heuristic generated that finds best ants and reinitiates searching process to come out of local minima and to identify ideal CH from a QOS perspective. This problem is seen as a graph in that each node's location is represented by x and y coordinate values and identified by a unique node number. A node is in the range of another node, computed by Euclidian distance $d(MN_{i,j}) = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$, node j is neighbour to node i . Hierarchical routing is undertaken with clustering, where paths are recorded between clusters and not between nodes. This reduces routing control overhead. ACO locates minimal CH sets, an iterative process with the local solution provides the output. CH selection is based on two aspects, pheromone value of each node and its visibility. Visibility is the number of nodes covered when the node is added to a CH set. Visibility changes as topology changes. Pheromone value of a node is updated during an algorithm's iteration. A node is assigned as a CH at initial iteration, and then selects the next CH based on the pheromone and neighbour nodes visibility. This continues till all network nodes are covered. A node is covered if it is a CH or falls within range of a CH already selected. A node pheromone value is updated whenever it is selected as a CH. Hence, the chance of a node being chosen as CH depends on pheromone value and visibility that alters as the algorithm goes through various iterations.

Each CH of a cluster maintains two index tables named Local Cache Index Table (LCIT) based on semantic dimension and Global Cache Index Table (GCIT) to ensure geographical dimension. LCIT has details of cached data in home clusters, whereas the GCIT has details of cached data in adjoining clusters. A CH predicts its cluster member's mobility by monitoring received signal strength (RSS) regularly [16]. When a node plans to move, its information is updated on both LCIT and GCIT. The CH is reselected during either power level or cache utilization is decreased beyond cluster members. Thus CH is adaptively changed based on performance and mobility.

When a data request is send from a node to its CH, it checks data in the LCIT. If present, cached data is send to the corresponding client. If data is absent in LCIT, CH checks its GCIT, to know about data item's availability in any adjoining

cluster. If present, data is send to the respective client that becomes caching node (CN). The objective of the proposed work is to discover better replaceable data in the cache using MA. The numerous papers have been proposed MA for problem domains such as combinatorial optimization [17], multi-objective optimization [18] and bioinformatics [19]. Hence, this paper proposed MA for optimal data replacement in cached data of all CNs.

3. OPTIMAL DATA REPLACEMENT

A novel data replacement policy is proposed for MANET to ensure data validity that enhances cache consistency. The data are considered as global and local based on the interest of the neighbours either in home cluster or adjoining cluster. The data that are accessed either by home cluster member or by adjoining cluster member is termed as local data. The other data are grouped based on two dimensions:

- i. *Geographical dimension*: When data are related to a specific geographical that are particular interest to the mobile users in close proximity.
- ii. *Semantic dimension*: When data are of interest to users that are semantically neighbours, even if not physically closed.

When a new data is arrived into the cache enough required space is to be released to store it, if cache space is not sufficient. Thus, selection criteria must be defined for the cache management service, in order to choose data that can be deleted. The users interest criteria ($C_{interest}$) is given in Eq.(1).

$$C_{interest} = \alpha C_1 + \beta C_g; \alpha + \beta = 1 \quad (1)$$

The weighing factors ' α ' and ' β ' are used for locating replaceable data. The increase in ' α ' reduces the globally required cached data and increase in ' β ' reduces the locally required cached data. Optimization is used to locate the feasible solution to replace the data. The MA is an optimization technique based on hybrid evolutionary computation. MA learns about individual cached data based on interest of users and frequency of data access rate to find the replaceable data.

This work proposes an MA inspired by the foraging behaviour of ants followed by a local heuristic search. The ants release pheromones on the path while accessing the data from neighbour's cache. Since more number of ants accesses this data, the pheromone concentration increases that indicate the access rate of the cached data; i.e. the chance is more for accessing that data by neighbours. The fitness value is computed for every individual cached data based on data access frequency within cluster, frequency of data updates and users interest by Eq.(2).

$$f(t) = \frac{\sqrt{2d_m e^{-\left(\lambda_l^2 + \lambda_g^2\right)}}}{C_n 2\lambda_u} \quad (2)$$

The data with larger fitness value denotes high frequency access rate and more neighbour's interest. The data is selected based on the geographical and semantic dimensions. This optimization work is carried out the replacement of cached data based on fitness value using Eq.(3).

$$f(t)D_i > f(t)D_j \quad (3)$$

Pseudo code

- i. Network contains N mobile nodes
- ii. Initialize the cluster configuration
- iii. Node MN_i sends beacon to the neighbours (MN_j) using ACO algorithm
- iv. Neighbour MNs compare pheromone and visibility
- v. MN with higher values is elected as ideal CH by heuristic search
- vi. MN gets desired data D_i from neighbours or remote source through home CH and becomes CN for D_i
- vii. Fitness value is calculated for every cached data $D_i \dots n$ at time t in all CNs individually using MA using Eq.(2)
 - a) Determine the number of cached data (C_n)
 - b) Determine the number of updates of every cached data by source (λ_u), jitter (d_m)
 - c) Determine the rate of data access frequency by neighbours in home cluster (λ_i) and adjoining cluster (λ_g)
- viii. Data newly arrived to CN when cache is full, then desirable space to be allotted
- ix. Proposed MA is applied on the cached data $D_i \dots n$ to locate better replacement based on fitness value using Eq.(3)
- x. The data with lower fitness value is selected for replacement and newly arrival data is cached
- xi. Even If space is not sufficient after single data replacement, then subsequent fitness value data is taken for replacement for new data using Eq.(4) then replaces both data.

$$f(t)D_i > f(t)D_j + f(t)D_k \quad (4)$$

4. SCENARIO SETUP

The propagation of radio signals used in communication typically obstruct by objects such as vehicles, walls, doors and trees without rigorous attenuation. This causes shadowing in signal propagation in hill stations. The simulation model designed for real scenario that included the obstructions (rectangle box, line) for significant results. When nodes crossing the line the link are considered as broken up to move out of the line. An awareness program in the hill station is considered for simulation with 60 people. The 12 CBR sources generated and 35 receivers resulting 35 CBR flows. The people are segregated into four teams (clusters) by men, women, and school and college students have been assembled in different rooms and make interaction (sharing data) with other team. The cluster contains people make movement randomly at 1m/s in and out of the rooms. The team leader (e.g. laptop) is assigned in each room for their assistance that is wirelessly connected with remote office and make movement inside the room at 1m/sec. Initially people accesses the data from the team leader then data is stores in the cache that would use by the neighbours in future. The data updates in remote office are pushed to the team leaders then send to the people (Caching Node) in respective team. The renewal of data is done by team leader before expires.

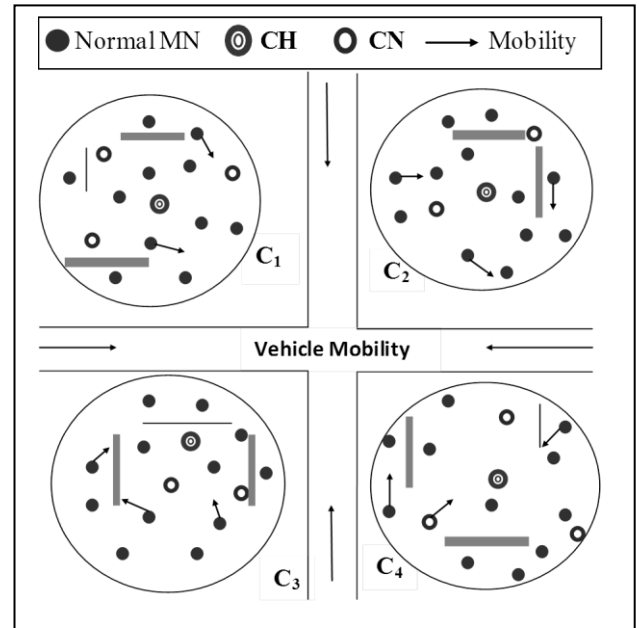


Fig.1. MNs Communication in Clusters

The cache replacement is performed during the new data accessed when cache is full. The proposed algorithm selected better replaceable data in the cache to improve the QoS. This scenario is considered to test the changes in the routes that affect the network performance. The different traffic flows are combined with low mobility factor to test the performance.

5. RESULTS AND DISCUSSION

The simulation for the proposed approach was carried out using Network Simulator-2 (NS-2) with channel capacity is 2 Mbps. The proposed optimized data replacement policy is evaluated for 60 nodes in a 3000×3000 m area with transmission range is 250 m. Assume that data query and update process are based on Poisson process. The simulated traffic is Constant Bit Rate (CBR) and run for 15 minutes (900 sec).

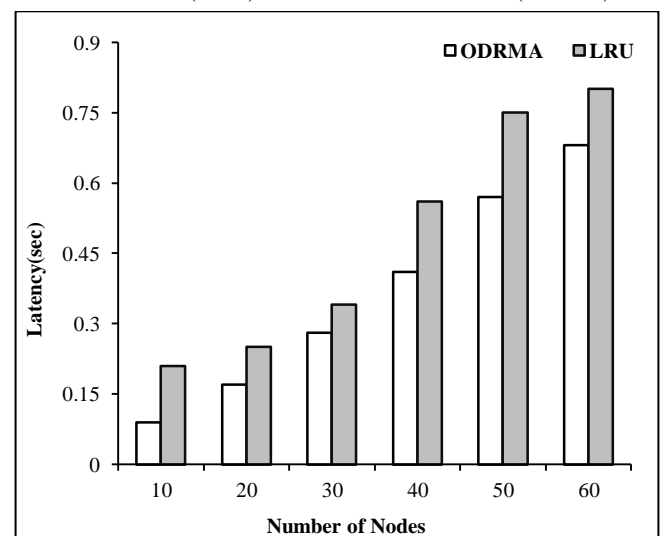


Fig.2. Latency Vs Nodes

The proposed Optimal Data Replacement policy using MA (ODRMA) is compared with Cluster Based Cooperative Caching Technique with LRU. The methods are evaluated for query latency, control overhead across network and packet delivery ratio (PDR).

The Fig.2 and Fig.3 show that the proposed ODRMA achieved comparatively lower query latency when compared with LRU.

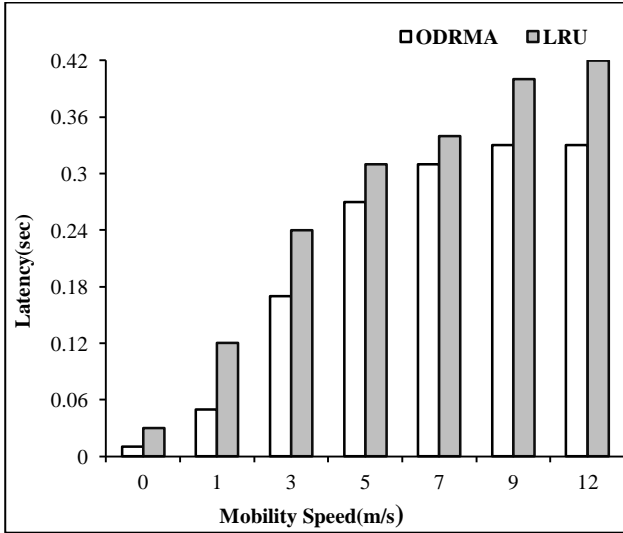


Fig.3. Latency Vs Speed

The proposed method optimizes based on the availability cache memory in the CH and its location with respect to its members and the server, thus ODRMA achieves 32%, 27% better query latency by varying number of nodes and mobility.

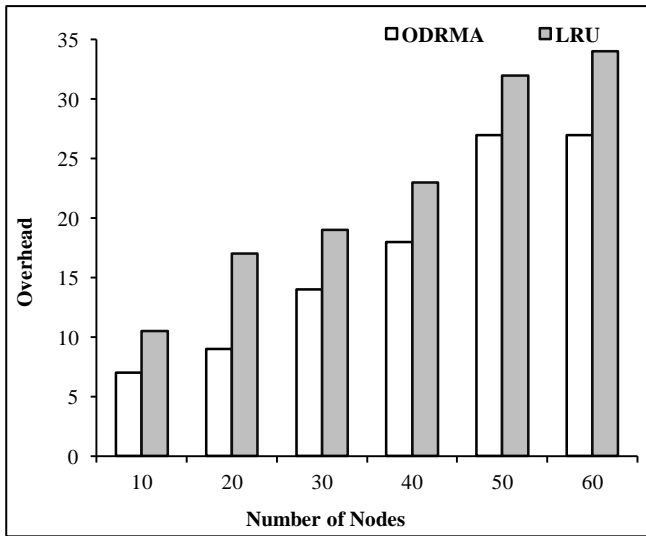


Fig.4. Overhead Vs Nodes

The Fig.4 and Fig.5 shown the control overhead achieved across the network. It is seen that the proposed ODRMA considerably reduces the overheads. The proposed method uses hierarchical routing based on clustering and creates minimal CH. Also, the paths are recorded between clusters instead of nodes. This reduces 45%, 33% control overhead than LRU.

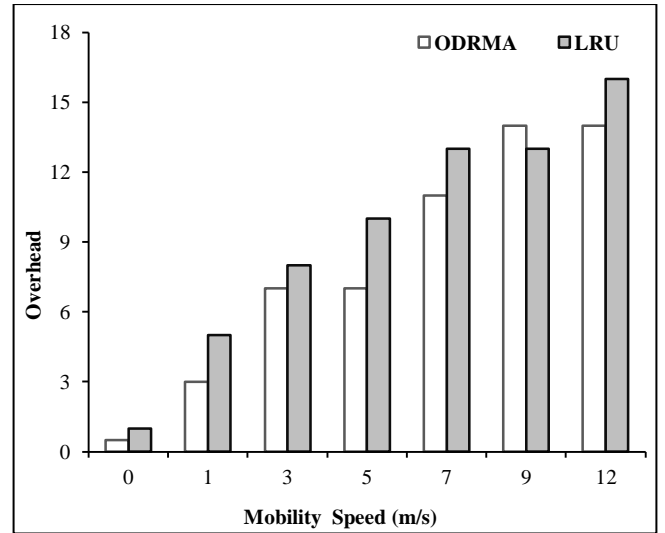


Fig.5. Overhead Vs Speed

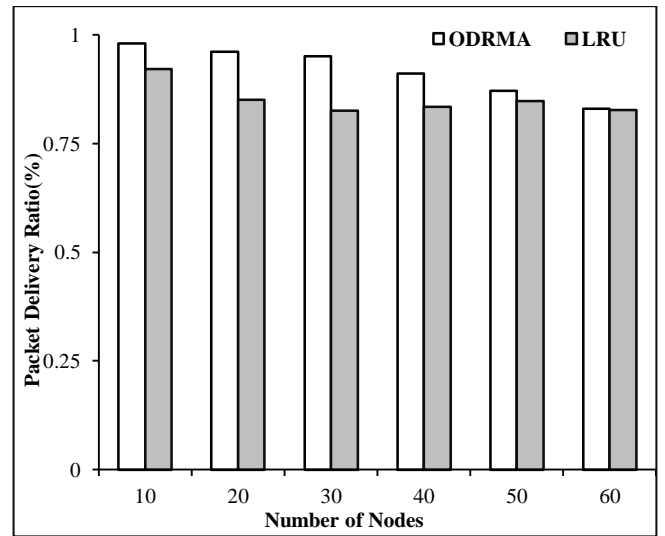


Fig.6. Packet Delivery Ratio Vs Nodes

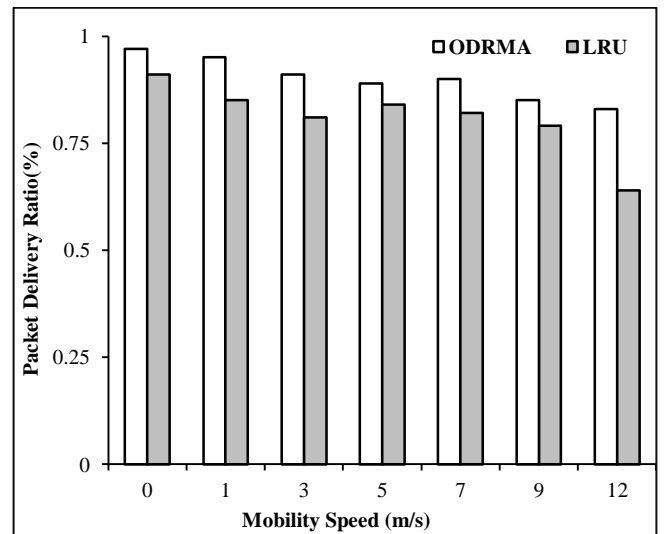


Fig.7. Packet Delivery Ratio Vs Speed

The results observed from Fig.6 and Fig.7, PDR is 39%, 27% higher for the proposed ODRMA when compared with the LRU. The optimization of the CH and the cache management that results in lower latency and overhead leads to better PDR.

6. CONCLUSION

A novel optimal data replacement policy using MA is proposed for MANET to make better replacement. This proposed technique maintains cache consistency with better data replacement using MA with ACO and local heuristic search. The proposed work uses ACO algorithm to addresses the CH selection that acts as a local server and MA to addresses the data that needs to be cached (caching policy). Simulations are conducted, and the proposed method improved the QoS for various number nodes and mobility compared with cluster based cooperative caching with LRU. Results demonstrated that the proposed method achieves higher PDR and lower latency and overhead.

7. FUTURE WORK

This study is simulated for ad hoc network with low mobility nodes. It could be extended with number of CHs, CNs and pause time. Moreover, proposed work is considered the textual data in the communication. The voice could be used in future work to enhance the comprehensibility.

REFERENCES

- [1] L. Hanzo and R. Tafazolli, "A survey of QoS routing solutions for mobile ad hoc networks", *IEEE Communications Surveys and Tutorials*, Vol. 9, No. 2, pp. 50-70, 2007.
- [2] L. Yin and G. Cao, "Supporting cooperative caching in ad hoc networks", *IEEE Transactions on Mobile Computing*, Vol. 5, No. 1, pp. 77-89, 2006.
- [3] N. Chand, R. C. Joshi and M. Misra, "Cooperative cache management in Mobile Ad Hoc networks", *Proceedings of the International Conference on Mobile Technology, Applications and Systems*, pp. 1-7, 2005.
- [4] Y. Zhang, X. Zhou, Y. Liu, B. Wang and S. Ci, "A novel cooperative caching algorithm for massive P2P caches", *Journal on Peer-to-Peer Networking and Applications*, Vol. 6, No. 4, pp. 425-433, 2013.
- [5] P. Kumar, N. Chauhan, L. K. Awasthi and N. Chand, "Proactive approach for cooperative caching in mobile adhoc networks", *International Journal of Computer Science Issues*, Vol. 7, No. 8, Issue. 3, pp. 21-27, 2010.
- [6] M. Boddu and K. S. Joseph, "Improving data accessibility and query delay in cluster based cooperative caching (CBCC) in MANET using LFU-MIN", *International Journal of Computer Applications*, Vol. 21, No. 9, pp. 37-42, 2011.
- [7] S. Lim, W. C. Lee, G. Cao and C. R. Das, "A novel caching scheme for improving internet-based mobile ad hoc networks performance", *Ad Hoc Networks*, Vol. 4, No. 2, pp. 225-239, 2006.
- [8] P. T. Joy and K. P. Jacob, "Cooperative caching techniques for mobile ad hoc networks", *Proceedings of the International Conference on Data Science and Engineering*, pp. 175-180, 2012.
- [9] H. Safa, F. Deriane and H. Artail, "A replication based caching strategy for MANETs", *Proceedings of the International Conference on Selected Topics in Mobile and Wireless Networking*, pp. 139-144, 2011.
- [10] H. Shen, M. S. Joseph, M. Kumar and S. K. Das, "PRECinCt: A scheme for cooperative caching in mobile peer-to-peer systems", *Proceedings of the 19th IEEE International Parallel and Distributed Processing Symposium*, pp. 57a, 2005.
- [11] N. Chauhan, L. K. Awasthi and N. Chand, "Cooperative data caching with prefetching in mobile ad-hoc networks", *Proceedings of the First Asian Himalayas International Conference on Internet*, pp. 1-4, 2009.
- [12] W. E. Hart, N. Krasnogor and J. E. Smith, "Memetic evolutionary algorithms", *Recent advances in Memetic Algorithms Studies in Fuzziness and Soft Computing*, Vol. 166, pp. 3-27, 2005.
- [13] Y. S. Ong, M. H. Lim, N. Zhu and K. W. Wong, "Classification of adaptive memetic algorithms: a comparative study", *IEEE Transactions on Systems, Man and Cybernetics Part B: Cybernetics*, Vol. 36, No. 1, pp. 141-152, 2006.
- [14] M. Dorigo, M. Birattari and T. Stutzle, "Ant colony optimization: Artificial ants as a computational intelligence technique", *IEEE Computational Intelligence Magazine*, Vol. 1, No. 4, pp. 28-39, 2006.
- [15] V. Maniezzo and A. Carbonaro, "Ant colony optimization: An overview", *Essays and Surveys in Metaheuristics*, pp. 469-492, 2002.
- [16] P. Kuppusamy, K. Thirunavukkarasu and B. Kalaavathi, "Cluster based cooperative caching technique in mobile ad hoc networks", *European Journal on Science and Research*, Vol. 69, No. 3, pp. 337-349, 2012.
- [17] P. Merz and B. Freisleben, "Fitness landscape analysis and memetic algorithms for the quadratic assignment problem", *IEEE Transactions on Evolutionary Computation*, Vol. 4, No. 4, pp. 337-352, 2000.
- [18] J. D. Knowles and D. W. Corne, "M-PAES: A memetic algorithm for multiobjective optimization", *Proceedings of the 2000 Congress on Evolutionary Computation*, Vol. 1, pp. 325-332, 2000.
- [19] N. Krasnogor, A. Aragón and J. Pacheco, "Memetic algorithms", *Metaheuristic Procedures for Training Neural Networks*, pp. 225-248, 2006.