2.1 Introduction

Design of distributed database involves two major design issues: fragmentation of the global database i.e. design of fragmentation schema and allocation of fragments over the communication networks i.e. design of allocation schema. Both fragmentation and allocation have an important role to play in the development of a cost effective distributed database system [78]. Fragmentation problem has been studied extensively in the context of horizontal fragmentation [7, 9, 16, 22, 29, 39, 78, 79, 87, 107], vertical fragmentation [7, 9, 29, 49, 56, 58, 59, 74, 75, 76, 78] and mixed fragmentation [77]. Since, the present study concentrates on fragments allocation problem assuming that database is already fragmented, so only previous works related to fragment allocation in the design of distributed database has been presented in this chapter. Previous works related to fragments allocation problem can be divided into two different parts: static allocation and dynamic allocation. Data in distributed database system is allocated according to two different types of access patterns: static and dynamic [78].

- **Static Allocation**: In a static environment, the access probabilities of the applications running on different site to fragments never change i.e. the access pattern are static.

- **Dynamic Allocation**: In a dynamic environment, the access probabilities of the applications running on different site to fragments change over time i.e. the access pattern are dynamic.

2.2 Static Allocation

Allocation problem is first studied from file allocation point of view. Chu [32] was first to investigate the file allocation problem. He formulated the file allocation problem into a non-linear 0-1 programming problem. A non-linear 0-1 programming problem can be solved with linear integer programming techniques. He has given an optimization
model to minimize overall storage and transmission costs under the constraints of response time and storage capacity with fixed number of copies of each file.

Casey [21] further investigates the Chu’s allocation model and relaxes the assumption of fixed number of copies. The stress was given on the difference between updates and retrieval. Eswaran [38] proved that Casey’s formulation was NP-Complete, so finding optimal solution is not computationally feasible. Therefore, he suggested heuristics rather than deterministic techniques to solve the file allocation problem.

Chen and Akoka [28] developed an optimization model for a distributed information system considering the processing power, allocation of programs and databases, and capacity of the communication lines. Bounded branch and bound integer programming technique is proposed to achieve the optimal solution of the model.

Ceri et al. [23] considered the problem of file allocation for typical distributed database applications. They developed an optimization model for a non-replicated allocation of data in a linear 0-1 programming problem form. Horizontal fragmentation is used as an input for the allocation model. The main objective of the model is to minimize the total transaction processing cost. Decomposition heuristics are developed due to the complexity of the problem. Ceri et al. [23] suggested that once the optimal solution has been found for non-replicated environment then replication can be handled easily by applying greedy approach.

Wong and Katz [104] suggested local sufficiency as a measure of parallelism in a distributed database. They have suggested three different approaches for replication of fragments, each having different blend of cost and benefits.

Apers [10] proved that the fragment allocation problem in distributed database is all together different from the file allocation problem. It is shown that the problem of determining a non-redundant allocation of fragments is NP-hard. Heuristics and optimization algorithms are proposed for non-replicated data allocation to minimize the total data transmission cost during the execution of a set of transactions. Simulation results show that the optimal algorithm performs better than heuristic algorithm. He also discussed a framework for the management of allocation in distributed databases for centralized as well as decentralized environment.
Ceri et al. [26] have given a general framework for the design of data distribution. They have presented an entity-relationship schema of the design data dictionary. The data dictionary stores all the information required for the design of distributed database. They presented an integrated toolset for the optimal design of data distribution using Divide- Conquer solution methods.

Cornell and Yu [36] proposed an integrated methodology to assign relations over the network and determine join sites simultaneously. The integrated methodology is divided into two separate stages. In the first stage, each query is divided into a sequence of steps of relational algebra operations. The output of the first stage is used as input for allocation of relations and selection of the join sites. This problem is formulated as linear integer programming problem. The objective of the problem is to minimize total communication. The processing power, communication capacity and the storage capacity of each site are the constraints for the optimization. Cornell and Yu [36] do not consider the effect of replication of data and update operations of the queries during the development of the methodology.

Ciciani et al. [33] developed an approximation model to find out the effect of data replication on the performance of distributed database system. Primary copy approach is used to handle replication of data. They have found that the concurrency control protocol has an impact on the optimal number of replicates. Replication can improve the response time under optimistic and semi-optimistic concurrency control protocols. It was observed that the optimal replication of the data improves the response time and communications overheads.

Chiu and Raghavenda [31] presented an allocation model to enhance the reliability of the system with the use of triple module redundancy (TMR) scheme. Triple module redundancy scheme ensures that each query request must be executed by at least three database servers on the communication network. The allocation problem is converted into a 0-1 integer programming problem. The Lagrangian relaxation technique is used to solve the problem. The goal of the allocation model is to discover the number of database servers and their respective location in order to minimize the total operational cost of a distributed database system.

Blankinship et al. [17] developed an iterative heuristic method to solve two NP-hard problems (data allocation and query optimization) simultaneously. Network sites and
topology, database unit of allocation, number of queries and their frequencies are the
input information require for the iterative method. The optimization iterative method
helps to find out a combine local minimum of both the data allocation cost and query
strategies cost. Fragments are allocated to the site, which is requesting them most
frequently. Replication of data is not considered in them.

Ram and Marsten [81] have given a model of allocation of data in distributed databases
by incorporating the “WRITE LOCKS ALL-READ LOCKS ONE” concurrency
control mechanism. An algorithm is developed based on the implicit representation of
Variable Upper Bound to solve the allocation model. They observed that the
concurrency control mechanism is an integral part of distributed database systems.

Lin et al. [57] proposed a simple polynomial time heuristic algorithm for data
allocation to minimize the overall communication cost. The proposed algorithm
considers physical network and transaction processing strategies for the allocation of
data.

Corcoran and Hale [35] presented a genetic algorithm (GA) to allocate fragments in a
distributed database system. Objective function for allocation is the total transmission
cost of executing a set of queries over all the sites of the network. The transmission cost
considers only the retrieval frequency of the different sites to all the fragments and
moreover replication of fragments is not taken into consideration. Performance of the
proposed GA is compared with the greedy heuristic and GA is found to have superior
performance than that of greedy heuristics. They observed that the performance of GA
does not degrade as the size of search space increases as compare to greedy approach.

Reid and Orlowska [82] proposed a model to allocate tables of a relation database to
the communication network so that the total cost of executing a set of join queries can
be minimize. The model describes the data allocation problem as an optimization
program having an integer linear program. The developed optimization program
achieved a minimal total cost for execution of a set of queries with permissible
replication. Branch-and-bound and cut-set techniques are suggested to solve this
problem.

March and Rho [69] extend the work of Cornell and Yu [36] to include data replication
and concurrency control mechanism. They developed a comprehensive mathematical
model for allocation of data as well as operations to nodes during the design process of
a distributed database. Network communication information, local processing power of each site and data storage cost is considered which the development of the model. The mathematical formulation is solved using an iterative genetic algorithm i.e. a genetic algorithm within a genetic algorithm. Outer genetic algorithm is for fragment allocation and inner genetic algorithm is for operation allocation.

March and Rho [70] analyze the performance of March and Rho [69] over various control parameters of genetic algorithm. Quality of the solutions provided by March and Rho [69] are analyzed over different pool size and crossover operators.

Lin and Orlowska [60] transformed the data allocation problem into an integer linear program. They investigate the data allocation problem to minimize the total communication cost of executing a set of transactions. Data replication and both read and update transaction are considered while allocating data over the communication network. Lin and Orlowska [60] have suggested that once the data allocation problem is converted into an integer linear program than the probability of finding a polynomial time bounded solution is quite high.

Kowk et al. [54] developed a query driven non-redundant data allocation of multimedia data objects in distributed database system. Data allocation problem has been formulated as an optimization problem. Three different techniques i.e. max-flow min-cut, state-space search and graph partitioning heuristics are used to solve the problem. Max-flow min-cut technique transforms the data allocation problem into network-flow problem and hill-climbing approach is used to find out the optimal solution. The data allocation problem is also transformed into state-space search problem and solved by best-first search algorithm. Graph partitioning technique uses two clustering heuristics to solve the problem.

Lim and Ng [56] proposed an integrated approach for vertical fragmentation and data allocation. Maximal locality of query evaluation and minimization of communication cost is considered for the integrated design approach. Three different algorithms for vertical fragmentation and one algorithm for allocating rule and fragments have been proposed by the authors.

Sarathy et al. [86] modeled a constrained nonlinear 0-1 programming formulation for allocating copies of relations from a global database to different sites of the network. The non-linear 0-1 programming formulation is then linearized and solved by the use of
subgradient optimization. The objective is to minimize the total cost of transmission which executing a set of queries from various sites of the communication network.

Karlapalem and Pun [52] proposed a query driven data allocation approach by combining the data allocation problem with the query execution strategy. A site-independent fragmentation dependency graph is used to check the dependency between different fragments accessed by a query. The data allocation problem has been studied for query-site and move-small query execution strategies. They developed two algorithms for query-site and move-small query execution strategy for non-redundant data allocation problem.

Daudpota [37] proposed a method to develop a model of data allocation for distributed database system. The method consists of five steps: collection of global relations; analysis of frequently asked queries; fixing objectives of data allocation; transformation of global relations into fragments; and allocation of fragmented relations to various sites of network. Based on these five steps, a model of data allocation is constructed. A heuristic algorithm named TGTF was derived for the transformation of global relation into fragments and their allocation in replicated manner.

Tamhankar and Ram [98] developed an integrated methodology for fragmentation and replicated allocation of data featuring concurrency control mechanism. The methodology is divided into four steps: primary distribution and three secondary distributions. First step, i.e. primary distribution, deals with the design objectives at application level. Output of the first step is a distribution matrix which designates the data distribution for each site. Second, third and fourth steps, i.e. secondary distribution, of the methodology deals with the response time, availability of the data and optimization of storage space respectively. A case study of manpower distribution in a distributed organization has been taken to show the performance of the proposed methodology. Barney and Low [12] extended the work of Tamhankar and Ram [98] for object-oriented databases by including the process workload estimation.

Barker and Bhar [11] proposed a graphical optimization technique for non-replicated allocation of fragments in distributed objectbase systems. A non-redundant cost model is developed for the allocation. To achieve a “near optimal” allocation of fragments, a heuristic algorithm is proposed by exchanging and/or moving fragments between every pair of site of the network.
Huang and Chen [50] proposed a comprehensive model for replicated allocation of fragments using the behavior of transactions in distributed databases. The cost model is developed based on the size of the fragment, retrieval and update behavior of all the transaction, and data transfer cost over the communication network. Two heuristic algorithms are proposed to minimize the total communication cost for the execution of a given set of transactions. Initially, all the fragments are allocated to each site that needs them. First, heuristic algorithm removes the replicas of fragments from the initial fragment allocation to minimize the communication cost. The second heuristic algorithm removes the replicas of fragments from the initial allocation based on the updates of each site during the execution of set of transactions. It is an attempt to find out “near-optimal” solutions. Results of the proposed heuristic algorithms are compared with Lin et al. [57].

So et al. [95] developed a probabilistic navigational model for data allocation in distributed hypermedia databases under the average response time constraint. A Hill-climbing heuristic algorithm is proposed for allocation of multimedia data object. It was observed that the proposed algorithm is a good choice for small problem size.

Ahmad et al. [8] proposed evolutionary algorithms for non-redundant data allocation in distributed database systems. Three different evolutionary algorithms and search based heuristic are introduced to solve the problem data allocation problem. The data transfer cost model has been developed using site-independent fragment dependency graph representation. The main objective is to obtain high quality solution (i.e. minimum data transfer cost) with fast turnaround time. Evolutionary algorithms are genetic algorithm (GA), simulated evolution algorithm and mean field annealing algorithm where as neighborhood search algorithm is based on search based heuristic. All the algorithms are compared on the quality of solution provided for data allocation and execution time. They have suggested that when efficiency and solution quality are equally important then genetic algorithm is an attractive solution. Karlapalem et al. [51] also empirically evaluated the performance of these four algorithms for allocation of data in distributed multimedia databases.

Loukopoulos and Ahmad [62] formulated the data allocation problem as a constraint optimization problem. They proposed simple replication algorithm (SRA) based on the greedy heuristic and genetic replication algorithm (GRA) based on genetic algorithm to solve the problem. Comparative results show that GRA is superior to SRA.
Menon [72] has presented an integer programming formulation for the non-redundant version of the fragment allocation problem. His work is an extension of the work done by Sarathy et al. [86]. Processing and storage capabilities of the different sites in the communication network are added as a constraint to the formulation of Sarathy et al. [86].

Silva and Dissanayake [88] proposed an integrated solution of fragmentation and allocation problem in distributed database design. Two different algorithms are proposed for optimal design of distributed database. First algorithm fragments the global relation into vertical fragments based on the read and update requirements of different sites. The second algorithm allocates vertical fragments to various sites by using mimic cultural evolution technique.

Ma et al. [63] proposed a generalized framework for distribution design of higher-order data models. Fragmentation, allocation and replication are incorporated in proposed framework. An integrated heuristic approach is used for fragmentation and allocation. A cost model for query processing cost is constructed using query tree. Impact of horizontal as well vertical fragmentation on the query cost has been studied. The work is divided into three parts. The first part finds out the initial allocation of fragments. Initially, fragments are allocated either to the site, where they are most needed or to the sites that will have minimum transmission cost. The second part further evaluates the initial allocation and verifies that, whether further fragmentation improves that performance of data allocation or not. The third part puts a restriction on the query frequency selection predicates.

Hababeh et al. [45] designed an integrated methodology for clustering the sites of communication network and replicated data allocation in distributed database system for high performance computing. Sites of the communication network are grouped into different clusters based on some clustering decision value. Once the site of communication network is divided into different clusters then fragments are allocated to these clusters and their respective sites. The decision of allocating a fragment to a cluster is taken on the basis of the cost of allocating a fragment to the cluster and cost of not allocating a fragment to the cluster. If the cost of allocating a fragment is more than the cost of not allocating then that fragment is allocated to the respective cluster otherwise not. The main idea is to reduce the overall communication over the network.
and to improve the performance of distributed database system by increasing availability and reliability.

Rahmani et al. [80] have tried to improve Hababeh et al. [45] allocation by incorporating genetic algorithm. Roulette wheel method is used to select two individuals from the population and single point crossover method is used for crossover operation. Objective function that has to be minimize is the total data transmission cost. Total data transmission cost includes the cost of local retrievals, local updates, remote retrievals, remote updates and storage.

Adl and Rankoohi [6] proposed an algorithm (ACO-DAP) based on the ant colony optimization (ACO) meta-heuristic for non-replicated allocation of data in distributed database systems. The cost function that has to be minimize is the total data transmission cost under the storage capacity constrain. Three different versions of ACO-DAP are used to explore the performance of the proposed heuristic.

Mamaghani et al. [68] proposed a hybrid evolutionary approach for data allocation in distributed database system. Hybrid approach is the combination of object migration learning automata and genetic algorithm. An object migration learning automata is used to represent chromosome. The objective of the hybrid approach is to minimize the total data transmission cost.

Tosun et al. [99] proposed three different heuristic algorithms for non-replicated fragment allocation. Genetic algorithm, Simulation Annealing algorithm and Fast Ant Colony algorithm are used to solve the fragment allocation. Comparison of these algorithms is carried out on the quality of solution provided for data allocation and execution time.

2.3 Dynamic Allocation

Apers [10], Lin et al. [57] and Loukopoulos and Ahmad [62] have also investigated the data allocation problem in distributed databases for dynamic environment.

Apers [10] proposed heuristic algorithm for non-replicated data allocation to minimize the total data transmission cost during the execution of a set of transactions for dynamic environment. Schedules of all the transactions are recomputed for the initial allocation to deal with the dynamic environment. The current allocation is change according to the
cost of recomputed schedules. Schedules of all the transactions are again computed for the new allocation to check the performance.

Lin et al. [57] proposed a heuristic algorithm for dynamic data allocation to minimize the overall communication cost. The heuristic algorithm iteratively refines the initial allocation through local modification to minimize the overall communication. The local modification is the process of adding a copy of fragment to a site or by removing a copy of fragment from a site. Iteration process of the algorithm will stop if overall communication cost does not decrease. But in practice Lin et al. [57] suggested a fixed number of iteration.

Loukopoulos and Ahmad [62] proposed an adaptive genetic replication algorithm (AGRA) based on genetic algorithm for dynamic environment. The proposed AGRA adjusts itself to the changing environment and data allocation schema is modified to get better performance in new environment.

Rivera-Vega et al. [83] suggested a heuristic strategy to solve the problem of redistribution of data in distributed databases. They investigated the problem of redistribution of data from three different prospective: due to physical change, due to logical change and combination of both. Redistributed problem is formulated into a linear 0-1integer programming problem. An approximation strategy is proposed to solve the problem in linear polynomial time. The objective of the approximation strategy is to minimize the transfer time during redistribution of data.

Chaturvadi et al. [27] developed an adaptive method for allocation data in distributed database environment using machine learning approach. A machine learning based time invariant fragmentation method (MLTIF) is proposed to minimize the data communication and update synchronization cost. MLTIF method automatically acquires information about the data usage of each site from the query history of the database. The acquired information is used to reschedule the allocation process.

Brunstroml et al. [19] proposed two heuristic algorithms (Simple Counter Algorithm and Load Sensitive Counter Algorithm) for dynamic data allocation in distributed database. Simple Counter Algorithm is proposed for reallocation of fragments due to change access pattern in distributed database environment. Load Sensitive Counter Algorithm is proposed to handle overloading of a site. Performance of the developed algorithms is studied on a local area network and a wide area network as well. It was
observed that the Simple Counter Algorithm is performing 30 percent more than the static allocation.

Wolfson et al. [102] proposed an adaptive data replication (ADR) algorithm to improve the performance of distributed database system. Adaptive data replication algorithm changes the replicated allocation scheme on basis of current access behavior of the transaction in a distributed network system. ADR algorithm incorporates the storage capacity constraint i.e. the storage capacity of each site is taken care of while changing the existing allocation schema. Issues of failure and recovery of the distributed database system are addressed during the adaptive replication process.

Kazerouni and Karlapalem [53] presented a stepwise redesign of distributed relational databases. Redesign of distributed database is divided into two different phases: split phase and merge phase. The split phase of redesign approach breaks a fragment into smaller fragments on the basis of transactions access behavior towards the fragment. A merge phase of redesign approach merged a set of fragments together as they are accessed by a set of transactions collectively. The goal of the redesign is to reduce the irrelevant data access and to decrease the overall data transfer cost. The stepwise redesign is instigated either after fixed number of transactions or fixed time interval. Kazerouni and Karlapalem [53] approach work for non-replicated situations.

An incremental growth framework for incremental data allocation and reallocation in distributed database systems was proposed by Chin [30]. This framework is invoked in a situation when the performance of the fall below than a suitable threshold. The new servers are added incrementally in the system to enhance the performance at acceptable level. The data is reallocated in the system after the addition of each new server. Two heuristic algorithms (Partial Reallocate and Full Reallocate) are proposed for reallocation of data. Both the heuristic algorithms reallocate the data on the basis of objective cost function by using greedy, hill-climbing approach. The objective cost function consists of three different costs: cost of data transmission, local processing cost and queuing cost.

Mei et al. [71] proposed a model for dynamic file allocation schemes in a large-scale distributed file system to measure the assurance. The proposed model takes up the fragmentation, replication and security issues together during reallocation. An optimal dynamic distributed allocation algorithm is presented to make sure that reallocation of
the fragments is transparent and automatic. The algorithm converges to optimal solution according to global access pattern. Optimality is defined in terms of maximizing the assurance of file. The dynamic algorithm is developed to analyze high assurance, availability, performance, and scalability of distributed system.

Ulus and Uysal [100] proposed a heuristic algorithm named threshold algorithm for dynamic data allocation for non-replicated distributed database systems. The threshold algorithm is an extension of Simple Counter Algorithm given by Brunstroml et al. [19] to improve the performance of distributed database system. The threshold algorithm reallocates the fragments according to changing access pattern of distributed database queries. The threshold algorithm changes the ownership of fragment from one site to another site according to frequency of remote accesses.

Abiteboul et al. [5] provided a framework for distribution and replication of dynamic XML documents for distributed computing. A comprehensive cost model is developed for query evaluation to determine the cost of queries. A dynamic replicated algorithm is proposed to reduce the global costs of query execution as many sites can be collaborated to execute a query.

Buchholz and Buchholz [20] studied the problem of replica placement in adaptive content distribution network. A model is introduced for cost-quality-optimized content networking. The replica placement problem is converted into the knapsack problem. Plan ranking and greedy ranking heuristic algorithms are proposed to solve the problem. But no experimental work is done to prove the efficiency of the proposed algorithm.

Gog and Grebla [40, 43] proposed an evolutionary fragmentation and allocation (EFA) algorithm for re-fragmentation and re-allocation in dynamic distributed database systems. The evolutionary fragmentation and allocation (EFA) algorithm re-fragment and re-allocate the fragments for redesign phase using genetic algorithm. The main objective the proposed allocation is to minimize the total data transmission cost.

Lin and Veeravalli [61] designed a dynamic object allocation and replication algorithm for distributed systems with centralized control. The new designed algorithm named as dynamic window mechanism (DWM). A mathematical cost model is developed to determine the costs involved in servicing a request. The dynamic window mechanism (DWM) algorithm transforms the existing allocation scheme to new allocation schema
to adjust with the changing access behavior. The objective of the DWM is to minimize the total data transmission cost.

Gu et al. [44] investigated the problem of replicated data allocation for distributed databases with buffer constraints. The dynamic window mechanism (DWM) algorithm of Lin and Veeravalli [61] was used for dynamic replicated allocation of data. DMW algorithm makes a decision of saving a read request or not saving a read request depends on whether it can minimize the total cost of a request sequence or not. Two models have been developed for homogeneous and heterogeneous data objects. Three different strategies (No Replacement, Least Recently Used and Least Frequently Used) are employed on both developed models to check the performance of the proposed DWM algorithm.

Haddad and Charrada [47] proposed a dynamic replicated database placement on large scale system such as grid environment. A fragment reallocation algorithm is developed to change the allocation schema. The developed algorithm reallocates the fragments according to query patterns and the grid sites storage capabilities. The objective of this reallocation algorithm is to decrease the data transmission cost and to increase the resource utilization.

Basseda et al. [13] recommend a novel dynamic data allocation algorithm for non-replicated distributed database systems. The novel algorithm named Near Neighborhood Allocation (NNA) algorithm reallocates the data fragments according to the change in data access pattern in the communication network. The network topology and routing for specifying destination is considered in the proposed methodology. The NNA algorithm moved the data fragment to a site which is the neighborhood of current owner of the fragment and on the path to the site having maximum access counter. The objective the proposed algorithm is to minimize the total data transfer cost during the execution of a set of transactions.

Abdul-Wahid et al. [4] proposed a bio-inspired replication approach for adaptive distributed databases. The new developed approach is based on swarm intelligence. A system of mobile agents, called Pogo ants, is designed for the management of partial replicated database system. This system creates the replicas of data fragments dynamically on the sites which are having frequent access over these fragments. These replicas of data fragments are removed after being ideal for a fixed period of time from
the respective sites. The main goal of the proposed approach is to minimize the inter-site communication and response time.

Uysal and Ulus [101] formulated a Markov chain model of threshold algorithm [100] for non-replicated allocation of data in dynamic distributed database systems. Finite-state Markov chain is used for the threshold algorithm modeling. Change in access probability and change in threshold value are used to analyze the behavior of a fragment in the system. In this study, it was observed that the fragment tends to reside more at the site with higher access probability as the threshold value of the algorithm increases.

Tâmbulea and Horvat [96] proposed a model for dynamic redistribution of data fragments in distributed databases. The statistical information related to queries and their read/write requests for different fragments is gathered for a specific time period. Tâmbulea and Horvat-Petrescu [97] also developed a model to evaluate the queries in dynamic distributed database environment. A heuristic algorithm is proposed to redistribute data fragments using statistical information related to read/write requests of different queries. The objective of the redistribute process of data fragments is to minimize the size of data transfer.

Basseda and Rahgozar [14] proposed a fuzzy based approach (FNA) to improve the performance of Near Neighborhood Allocation (NNA) algorithm given by Basseda et al. [13]. FNA uses differentiation of access pattern for dynamic allocation of data. Basseda and Rahgozar [14] observed that the fuzzy based approach (FNA) is performed better NNA for larger networks.

Hauglid et al. [47] presented a decentralized dynamic fragmentation and replication management (DYFRAM) approach for dynamic distributed databases. DYFRAM is an integrated approach for fragmentation, replication and reallocation. DYFRAM uses recent access history of different transaction in the communication network. The objective of DYFRAM approach is to maximize the number of local accesses as compare to the number of accesses from remote sites.

Abdalla [1] presented a data reallocation model for replicated as well as non-replicated distributed database systems. A heuristic algorithm is proposed for reallocation process. The algorithm reallocates the fragments under storage capacity and fragment limit constraints. The objective is to minimize the communication cost and response time.
Abdalla [2] proposed a heuristic technique to synchronized horizontal fragmentation and allocation in dynamic distributed database environment. The synchronized approach fragments a global relation horizontally based on the attribute retrieval and update frequency. A cost model for data allocation is developed under the constraint of sites storage capacity. The heuristic technique decides the allocation schema based on the fragment access pattern. The objective is to minimize the cost function i.e. total data transmission cost. Threshold values for average retrieval and update costs of all fragments individually are taken into consideration while taking the decision of replication.

2.4 Summary

Data allocation problem in distributed database design is NP-hard [10]. There are two methods to handle NP-hard problems [60]:

- **Heuristic Approach**: A heuristic approach may generate only a good approximation solution to the problem. Heuristic approaches are generally polynomial time bounded with respect to the input size [60].

- **Optimization Algorithm**: An optimization algorithm may always generate the optimal solution to the problem. But optimization algorithms are exponential time bounded with respect to the input size [60].

As shown in the last two sections of this chapter, most of the researchers have proposed either heuristic algorithms or optimization algorithms to solve the data allocation problem in distributed database system.

The present work will introduce two different meta-heuristic algorithms for both non-replicated and replicated static allocation of data. The first proposed algorithm is based on the biogeography-based optimization (BBO) [98]. The second proposed algorithm is based on the simplified biogeography-based optimization (SBBBO) [91]. The present work will also introduce a new heuristic algorithm named Threshold and Time Constraint Algorithm (TTCA) for non-replicated dynamic allocation of data. The TTCA for non-replicated dynamic allocation of data in distributed database system is developed to improve the performance of two existing approaches: Optimal algorithm [19] and Threshold algorithm [100].
In nutshell, data allocation in distributed database design is a combinatorial optimization problem with an objective function that has to be minimized or maximized with respect to a set of constraints. The objective of data allocation is to decrease data transmission cost, storage cost, processing cost, response time and to increase the overall performance of the system. This research will study the data allocation in the context of relational model. The proposed work will explore the data allocation problem in static as well as dynamic environment.