RESEARCH ARTICLE OPEN ACCESS

Offsite 2-Way Data Replication towards Improving Data Refresh Performance

Nazia Azim, Adnan Khan, Fazlullah Khan, Abdul Majid, Syed Roohullah Jan, Muhammad Tahir

Department of Computer Science
Abdul Wali Khan University Mardan
Pakistan

ABSTRACT

Many wide-area distributed applications use replicated data to improve the availability of data, and to improve access latency by locating copies of the data near to their use. High bandwidth of network and uninterrupted power supply are essential for a normal and smooth replication process frequently used during the refresh process. During replication a scenario is occurred of an instance failure will jeopardize the process and efforts. Instance failure occurs due to low bandwidth of network or interrupted power supply. Versions compatibility for RDBMS is also problematic during the refresh process, in Pakistan chief and reliable replication tools are expensive enough to deploy. Unfortunately there are concerned problems of continuous power supply and high rate of network bandwidth availability in south Asia especially in remote areas of Pakistan. The need for such a technique arised here that should omit the condition of online connectivity and also compatible with interrupted power supply and applicable with all versions in RDMS environment, in a distributed database system. In this paper we present a new offsite two-way data replication mechanism for distributed database system using less bandwidth of network and also reduce the network overhead without compromising consistency and data integrity. By all means to replicate data in existing infrastructure of Pakistan regarding the power supply and the existing network paradigm. In offsite replication a CDF file is created which captures the altered data (DML operations) during every transaction in any database server site. Through change data file, only changes will be forwarded from one server to another server. The offsite data replication plays an important role in the development of highly scalable, highly available, and fault-tolerant database system.

Keywords:- Bi-Directional, CDF, DML, Offsite

I. INTRODUCTION

Data replication is also called data consolidation in a distributed database environment, which is becoming a matured field in databases. Different types of replication methodologies [13, 16] depend on requirements and available resources of organization. Majority of the organizations is using data replications [9] in a distributed database environment to populate their reporting servers for decision making support Replicated data can be more fault-tolerant than un-replicated data, and use to improve performance [8] by locating copies of the data near to their use. Copies of replicated data are held at a number of replicas that consist of storage and a process that maintains the data copy. A client's process can communicate the replicas to read or update the data. Traditionally both the clients and replicas reside on hosts, which are connected to internetwork consisting of local-area networks with gateways and point-to-point links through the Quorum protocols [29]. Oracle,[20] one of the leading RDBMS vendors, provides Oracle Advanced Replication which is capable of handling both synchronous and asynchronous replications[12]. It replicates tables and supporting objects, such as views, triggers, and indexes, to other locations.

Scalability, performance, and availability can be enhanced by replicating the database across the servers that works to provide access to the similar database. In homogeneous or heterogeneous database environment, the connectivity between databases wants more network resources due to different frameworks.

In large-scale distributed system, Replication is a good technique for providing high availability [12] for data sharing across machine boundaries because each machine can own a local copy of the data. Optimistic data replication is an increasingly important technology. It allows the use of ATM banking with network failure and partitions and simultaneous cooperation access to shared data on laptops disconnected from Networks [2].

Replication is the key mechanism to achieve scalability and fault-tolerance in database [7]. Data replication is a fascinating topic for both theory and practice. On theoretical side, many strong results constraint what can be done in term of consistency e.g. the impossibility of reaching consensus in asynchronous system, the blocking of 2PC, the CAP theorem, and the need for choosing a suitable correctness criterion among the many possible .On the practical side, data replication plays a key role in

wide range of context: caching, back-up [23], high availability, increasing scalability, parallel processing, etc. Finding a replication solution that is suitable in as many such contexts as possible remains an open challenge. The following figure show a simple replication flow.

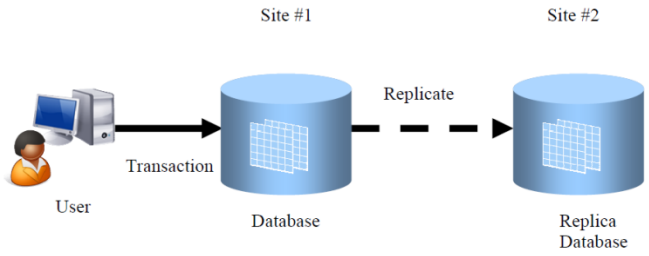


Figure 1.1: *simple replication flow*

II. DATA REPLICATION STRATEGIES

Oracle supports three types of replications.

2.1 MATERIALIZED VIEW REPLICATION

A materialized view is a replica of a target master from a single point in time [24]. These views are also known as snapshots. RDBMS uses materialized views to replicate data to non-master sites in a replication environment and to cache expensive queries in a data warehouse environment. The master can be either a master table at a master-site or a master materialized view at a materialized view-site. Where as in multi-master replication [13] tables are continuously updated by other master-sites, materialized views are updated from one or more masters through individual batch updates, known as a refreshes, from a single master site or master materialized view-site. Disadvantage of this type replication technique requires high speed network bandwidth [4] to refresh the data at master site after authentication also online connectivity for both sites. ***Figure 1.2*** illustrates materialized view flow

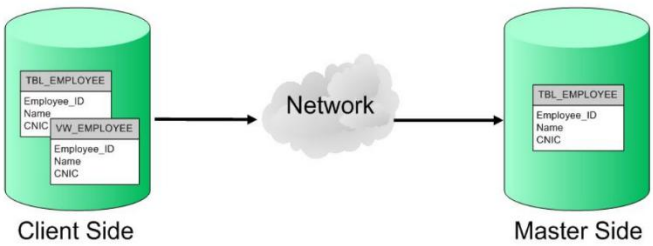


Figure 1.2: *Materialized View Replication*

2.2 MULTI-MASTER REPLICATION

Multi-master replication [10,13] is a kind of Synchronous replication [12] in which updates propagate immediately and ensures consistency. This is a procedural replication which runs same transaction at each site as a result of speed batch update. It can also be called 'peer-to-peer' or N-way replication [25]; also this is equally participating in an 'update-anywhere' model. It is a method of database replication allows data to store by a group of computers and updated by any member of the group. All members are responsive to client data queries. The multi-master replication system is responsible for propagating the data modifications made by each member to the rest of the group, and resolving any conflicts that might arise between concurrent changes made by different members [6, 21]. Disadvantages include loosely consistent, i.e. lazy and asynchronous, violating ACID properties. Eager replication systems are complex and increase communication latency. Conflict resolution can become intractable as the number of nodes involved rises and latency increases. The following figure describes Multi-Master replication process.

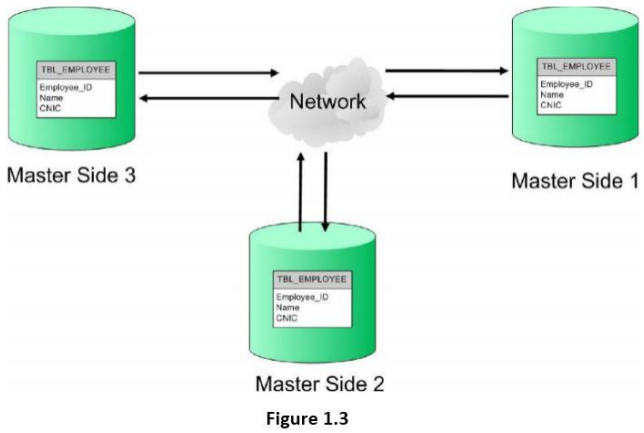


Figure 1.3: *Multi-master Replication*

2.3 STREAM REPLICATION:

Streams propagate both DML & DDL [1] changes to another (or elsewhere in same database). Streams are based on ***LogMiner*** which is an additional tool only available in enterprise editions of RDBMS. One can decide via rules which changes are needed to be replicated and can optionally transform data before applying it at the destination. LogMiner continuously reads DML & DDL changes from redo logs. It converts those changes into logical change records (LCRs). There is at least 1 LCR per row changed. The LCR contains the actual changes, as well as the original data. There are basically three processes in stream replication in the first process the changes are captured into log files. In the second step which is background process the data is propagated to the destination site. And in the last process the data is read from log files and replicated into the

destination database [20]. For full technical replication see [16].

Streaming replication process.

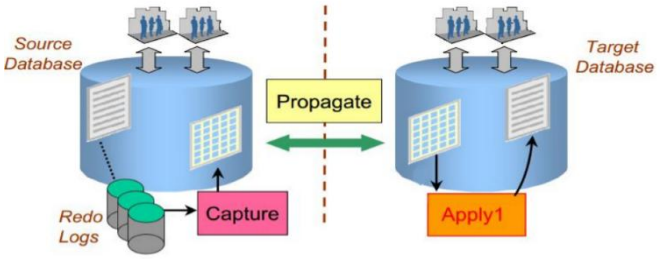


Figure 1.4

In the rest of this paper we present the problem statement in section 3 and section 4 describes the proposed technical replication. Section 5 shows the implementation of the discussed technical replication, section 6 shows the discussion on offsite data replication, Section 7 presents related work in offsite data replication, the conclusion is described in section 8 and section 9 shows the acknowledgment and at last the references.

III. PROBLEM STATEMENT

Many countries of the developing world are facing the electricity shortage. Pakistan is also a developing country and it is facing the acute shortage of electricity and low network bandwidth. High bandwidth of network and uninterrupted power supply are essential for normal and smooth replication process [4, 6]. Uninterrupted power supply can be provided by using high tech UPS available in the market however due to the 12 to 20 hours load shedding, any kind of high tech infrastructure cannot provide the required backup time for a smooth replication process. Due to the unscheduled load management plan; we conclude that throughout the year, distributed database servers can hardly be interconnected with each other [1]. In traditional replications techniques, network connectivity or data link is established for transformation of data throughout their replication process which may remain active for hours and increases the network traffic. To reduce the network traffic and overcome the consistent power supply issues we tried to present an alternative approach that can solve the network and power supply overheads. A new technique, the offsite replication is the server/server replication and this new technique does not require constant network connectivity and consistent power supply [28] to replicate data from source to destination. Offsite replication runs over two ways, replication over direct data path and replication via WAN Accelerators. Direct path include production site and remote site. Uses the backup proxy which accesses the backup server. Replication over WAN Accelerators uses weak network link. Challenges like disasters recovery, backup consolidation and cost effectiveness for the solution we use offsite replication. In offsite replication we use the Change Data File which takes less bandwidth and no constant connectivity from source to destination database server. The system at current is based on homogeneity. The proposed two-way replication model is implemented using standard DBMS and RDBMS tools (Oracle, SQLplus, PL-SQL, SQLyog wampserver etc).

IV. PROPOSED TECHNIQUE

To develop a new Bi-directional offsite replication technique for distributed databases environment that would transfer data using minimal bandwidth [21] without deactivating transactional operations neither at database server site1 nor at database server site2. The proposed technique not only reduces network overheads but also ensures effective and un-interruptible replication process without compromising on data consistency and integrity. Developed methodology can easily be adoptable, deployable and compatible with any RDBMS on any operating system platform [9].Our proposed system assures secrecy and preciseness with high availability and scalability of organizational data.

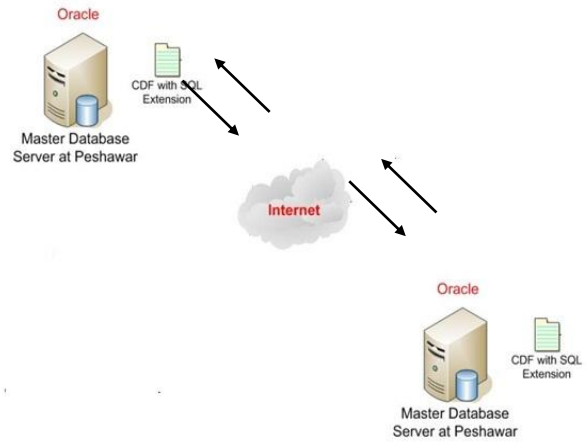
A local file is created which contain characteristics of Change Data File on any of the server side. This Changed Data File (CDF) tracks and captures only altered data / rows during the transactions in the database [14] at any server side table(s). The CDF is copied automatically at other server site on network using flash drive, Virtual Private Network (VPN), DSL and using email services by consuming minimal bandwidth. The discussed network infrastructure can easily be configured throughout the country without any additional resources. During the whole process of data replication i.e. CDF, the network resources were only consumed for small Period of time to transfer CDF file from server site1 to server site2. Offsite technique can improve data Refresh performance, because the systemcaptures the DML operations on daily basis for each record.

4.1 CHANGED DATA FILE (CDF):

As we know in traditional replication the whole record, data, or replication object is replicated from one site to another. In offsite 2-way replication the CDF file is created on any of server site in a distributed database environment which captures all the changes including row insertion, updating, deletion as well as the creation of new database objects. CDF contains DML operations [13]. The CDF provides real incremental dump facility. Oracle the leading database vendors, does not truly supports the real incremental backup utility especially in their express editions [23]. The commonly used EXP

utility of Oracle's products gives incremental backup to a certain limitations which creates backup of the whole table instead of the changed data so increasing size of the dump file [23].The incremental backup drops the existing table and re-creates the table for loading the complete data which is time consuming but also creates difficulties to identify the changed data. Suppose we have a table contains two million rows with size 100 MB and a DML operation i.e. a single row is updated at the time of incremental backup the whole table will be exported instead of a single row which was updated. At the time of import in destination database same table will be deleted and fresh copy will be imported and placed in a dump file for replacement with a size of 100 MB. When changes occur in server site1 then it is replicate to another server site2 through the Quorum-oriented Multicast protocols which helps in conflict detection [19].

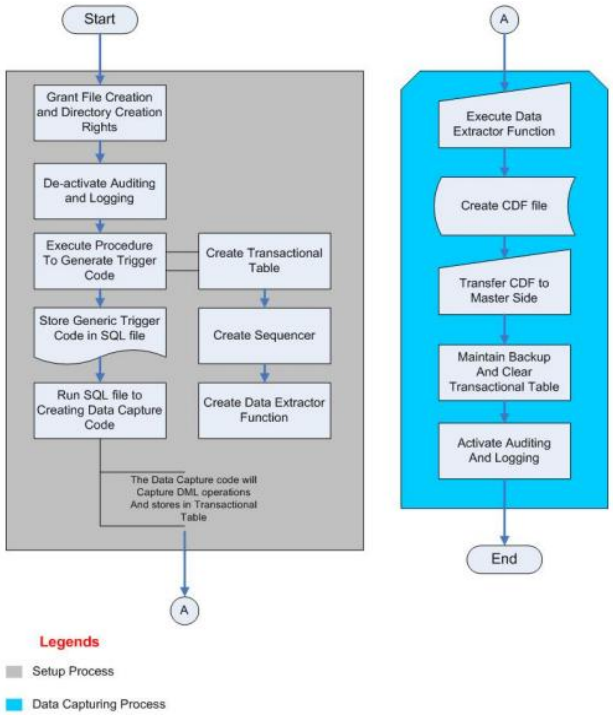
CDF supports huge data transformation from server to server by dividing the larger CDF into smaller chunks which can be easily transferred using less network bandwidth. The offsite system captures the changes and imports only changes occurring at the source server site and exports it to the destination database server. The changed data file captures only changes and exports it to the main database server.
The Proposed offsite CDF data consolidation technique is now deployed for two-way data replication which provided an effective data consolidation. Moreover the CDF can be successfully deployed in south Asia where high speed bandwidth and uninterrupted power supply is not continual for 24 / 7.



V. IMPLEMENTATION MODEL

The proposed technique could be implemented in many ways by the requirements of the organization. Let we have two databases MARDAN and PESHAWAR. MARDAN is the source server and PESHAWAR is the destination system or MARDAN is the destination system and PESHAWAR is the source server. As in two-way replication both sites are master so the CDF population at each site takes place after activating the replication which provides the data refresh performance. Through CDF technique all master server databases and web server are up to date [29-40]. In 2-way CDF methodology two different packages for master servers are installed.

Figure 1.6 *shows Master side1 process package1*



In ***figure 1.6*** the gray shaded block represents the setup process executed once for the all table. The data capturing process is presented in sky blue shade and is executed on each server side when data replication is required.

5.1 SERVER SIDE PACKAGE (SETUP PROCESS)

Directory and privileges are granted to MARDAN and PESHAWAR to create the CDF file in a specific directory. The username/password is first connected to oracle database. Then MARDAN is connected in given username/password schema to oracle database. Next the file is imported and connected to MARDAN. They import the export file and same is the process for PESHAWAR to export the import file. Like!

CONN A/A AS SYSDBA

GRANT DBA TO MARDAN IDENTIFIED BY MARDAN;

CONN MARDAN/MARDAN

CREATE OR REPLACE DIRECTORY DIR AS 'D:\MARDAN\THESIS_CODING;

The above coding called the server side setup process, which creates the directories for the Changed Data File to save the altered scripts. The GENERATE_TRIGGER_SCRIPT is executed to create generic code of transactional triggers for all tables in the schema of a particular table. The procedure reads data from data dictionary to generate code of transactional triggers which will capture the DML transactions. The generated transactional triggers code is stored in .SQL extension file named DYNAMIC_CODE.SQL. The code is written like this, CREATE OR REPLACE PROCEDURE GENERATE_TRIGGER_SCRIPT.

TBL_TRANSACTION table is created for storing captured transactions along with the serial no. The serial no used to keep a track of all the transactions. A sequencer is also created with a name as SEQ_FOR_TRANSACTION. Like!

CREATE SEQUENCE SEQ_FOR_REPLICATION START WITH 1 INCREMENT BY 1 NOCYCLE NOCACHE This sequencer provides serial numbers to every DML transaction. A function POPULATE_CDF is created to read data from TBL_TRANSACTION table. Due to this CDF file is created and populated, it is also called data extractor function.

The trigger is populated as!

CREATE OR REPLACE TRIGGER TRG_REP_TBL_REPLICATION

AFTER INSERT OR UPDATE OR DELETE

ON TBL_TRANSACTION

FOR EACH ROW

IF INSERTING THEN the rest of coding!

5.2 SERVER SIDE (DATA CAPTURING PROCESS)

When replication is required Data capturing process executes to populate CDF file and transfer it to other master side. Execute the function named as POPULATE_CDF. This creates and populates CDF with the transactional data stored in the TBL_REPLICATE table. Then transfer CDF file to destination master side either via VPN or email depending upon the file size. Create a backup of transactional data stored in the table named TBL_REPLICATE and truncate the table.

5.3 SERVER SIDE (LOADING PROCESS)

At each master side CDF file receives data extraction process started automatically after execution of the batch file. The batch file is executed manually or by operating system scheduler depending upon the requirement [5, 6]. The batch file finds the newly available CDF file; the data extraction process is the combination of multiple steps. De-activate default auditing and logging at master side performance. Receive CDF file either from VPN or email. Place the CDF file in the specific directory [41-48]. The Following ***figure 1.7*** depicts the entire workflow at master side:

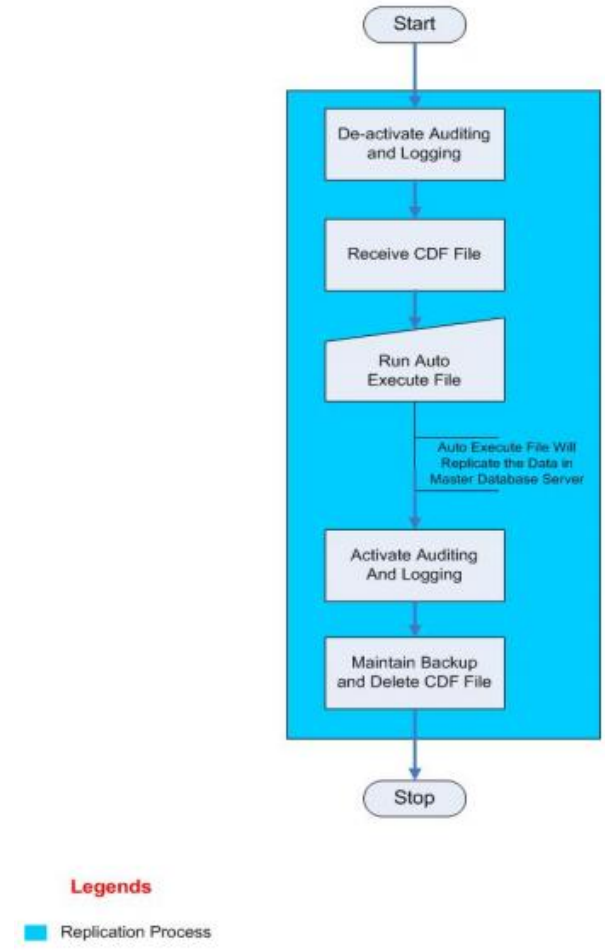


Figure 1.7 *Master side-1 process package2*

The same processes package1 and package2 are executed at all server sites

VI. DISCUSSIONS

Replication is widely used to achieve various goals in information systems, such as better performance, fault tolerance, backup, etc. Benefits of offsite 2-way

Replication like 24x7x365 availability of mission-critical data, Data integrity between source and target databases, disaster recovery and backup.

The widening demand supply gap has resulted in regular load shedding of eight to ten hours in urban areas and eighteen to twenty hours in rural areas. So the server site databases cannot connect with each other. Data replication is the most matured field in database world; however there are still some issues of network which is a vital part of replication process. The purpose of this study is to solve the network and load shedding problem using offsite two-way CDF replication [49-51]. Because through CDF data refresh performance remains up to date.

Suppose we have a table in MARDAN server with 11, 15193 records and the size of full database dump file is 147 MB. At initial full database dump file is imported in to other server PESHAWAR, for both the traditional and CDF methodologies. After a week 5831 transactions are performed on server MARDAN database. When the replication is required some operations are performed: Take full database dump of MARDAN with file size=149 MB time taken 4 min. Compress Dump file size = 22.39 MB Time Taken: 30 sec .Upload and email compressed dump file Time required 15 min Downloading compressed dump file time 7 mints Un-compress the dump file Time Taken: 30 sec Import dump file into dummy database time taken 4 mint. After that, delete all records from all tables of destination server database PESHAWAR Time Taken: 6 min. Select all records from dummy database and load them into destination database for all tables. Time Taken 6 min Delete dummy database. For replicating data of server MARDAN into other database server an average time required is approx. 45 min. The average time consumed for replicating MARDAN server's data to the destination is calculated using following formula:

Time (T) = Export Time (TE) + Upload Time (TU) + Download Time (TD) + Full Import Time (TI) + Shifting Data Time (TS).

After implementing CDF technique MARDAN server's data is replicated into destination server PESHAWAR'S database in approx. 5 min for 5831 transactions we have the steps: Execute POPULATE_CDF function. Time Taken: 1 min CDF file size = 0.71 MB after that Compress CDF files of size 0.0072MB Time Taken: 10 sec. Now transfer created CDF file via VPN or email to other database server, Time Taken: 1 min. Download and place CDF file in pre-defined directory on master database Time Taken: 1 min. Now Un-compress CDF files, Time Taken: 10 sec. we should Double click on the ORACLE.BAT the batch file Time Taken: 1.30 min. After execution of batch file the data is then loaded into destination database. The average time consumed for replicating data using CDF technique is calculated as:

Time (T) = Creation CDF file (TC) + Upload Time (TU) + Download Time (TD) + Extraction of CDF (TE).

Following table 1.1 elaborates the comparison between traditional and CDF methodologies for 5831 transactions.

TABLE 1.1

S #	Description	Traditional Approach	CDF Approach
1	Extraction of data to be replicated	4 min	1 min
2	File size	149 MB	.71 MB
3	File compression	30 sec	10 sec
4	File size after compression	22.39 MB	.0071 MB
5	File uploading	15 min	1 min
6	File downloading	7 min	1 min
7	File de-compression	30 sec	10 sec
8	Shifting of data into master database	16 min	1.30 min
	Total time	**43 min**	**4.5 min**

Following ***figure 1.8***depicts the table 1.1 more evidently:

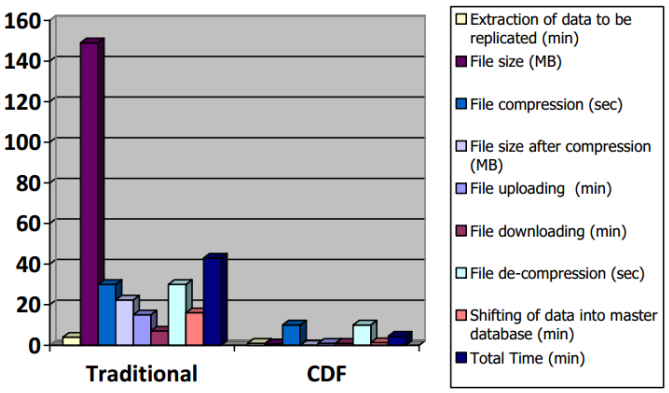


Figure 1.8

INCREMENTAL BACKUP USING CDF:

CDF provides a true incremental backup. In traditional mechanism for incremental backup [23], the whole table is exported no matter how many rows are altered. For example: A table TBL_SALES contains 100,000 number of records with size of 100 MB. If single record in a TBL_SALES is affected with a DML transaction then at the time of incremental backup the whole table will be exported instead of the changed record. However using the CDF methodology, incremental backup, exports only the changed data/rows instead of the whole table.

Table 1.2 *CDF incremental backup vs. Traditional backup*

Table Name	No of Rows	Table Size (MB)	Changed Rows	Traditional Incremental Backup File Size (MB)	CDF Incremental Backup File Size (MB)
CNG	5125	6	100	6	.0119
FAST FOOD	6234	7	100	7	.0119
PAY	13000	13	100	13	.0119
Tax	1200	12	100	12	.0119

The above table identifies the difference in size of true incremental backup using CDF and traditional backup technique.

SUPPORT FOR HETEROGENEOUS RDBMS:

The CDF methodology provides the facility of replication in heterogeneous RDBMS environment. Traditional and conventional technique supports only homogenous RDBMS. CDF is flexible used for any RDBMS and with DML transactions. CDF file is already used to replicate data in Oracle database. The CDF is compatible with all the versions of Oracle and MySQL.

The platforms used for CDF methodology of oracle and MySQL.

Table 1.3

Oracle RDBMS	MySQL RDBMS
Database 9i	MySQL 4.00
Database 10g XE	MySQL 4.90
Database 10g EE	MySQL 5
Database 11g XE	MySQL 5.02
Database 11g EE	

XE stands for Express Edition

EE stands for Enterprise Edition.

VII. REVIEW OF LITERATURE

Much research has been done on replicated data little of it relates directly to mobile computing. We surveyed the relevant work in replication for databases and remote distributed databases [9]. The system composed of several algorithms to assure secrecy and preciseness with availability of organizational data. The scenario gave the idea of a large organization composed of offices having own premises data centers in different locations. All data centers dedicated for organization managed by a central server, provided a platform for different query formats such as SQL or NoSQL and different database like MySQL, SQL Server and NoSQL. Thomson [1] system called Calvin designed a scalable transactional layer, all storage system implement a basic CRUD interface (create / insert, read, update, and delete). it is possible to run Calvin on top distributed non-transactional storage systems such as Simple DB. Calvin assuming that the storage system is not distributed out of box. For example the storage system could be a single-node key-value store that is installed on multiple nodes. The Calvin has three separate layers; sequencing layer, scheduling layer and storage layer. Functionalities partitioned across a cluster. McElroy & Pratt [20]. Oracle Database contains various styles from a master/slave replication where updates must be applied at master, a peer-style replication [22] where updates performed at one replica are forward other replicas. Sybase's SQL Remote product [27] supports optimistic client/server replication for remote database. It allow remote computer to selectively replicate a part of database. Mobile client maintains log of updates, which shipped to server using email when required. Liao [12] focuses issues of data synchronization and resynchronization in case of architecture failures, Difference between synchronous and asynchronous replication. The model divided the replication process in five phases, request forwarding, lock coordination, execution, commit coordination and client response Heinemann [26]. Much of the research is done on replication for database systems with mobile computing. "Consistency in a Partitioned Network: A Survey", contains a good survey on optimistic replication [11] number of optimistically replicated file systems include FicusCoda design to support mobility. Reconcile, Rumor provided useful lessons for development offsite data replication using less bandwidth methodology, including insights the costs and benefits of different methods of detecting updates, handling conflicting data, and data structures of update. Bayou [6] described a replicated storage system capable of supporting both file-oriented and database-oriented operations. Bayou takes application-aware approach to optimistic peer replication. In [23], we highlighted the limitation of incremental and cumulative backup techniques in available RDBMS. Recent work in the field can be found in [52-64].

VIII. CONCLUSION

RDBMS vendors are enticing / facilitating their customers with advance and easy to configure replication utilities in enterprises versions at an additional cost. Customers identify their requirements and purchase these utilities with respect to their needs after detailed analysis at their own. These add-ons utilities can easily be adopted

and implemented in Western countries where network communication is available consistently without any disruption and likewise the power supply is also unswerving. The dilemma of this country is that the high cost IT related development schemes are started ambitiously without any requirement assessment. To further worsen the situation, it is a common practice in administration that IT equipment and software are procured before recruitment of competent IT personnel due to the lapse of budget in every fiscal year. These purchases are made without any prior need- based assessment. In due course, at the time of software application deployment throughout the country or province, the purchased RDBMS does not support or have inadequate utilities to replicate the data from other remote servers into the centralized server usually installed in Provincial capitals and hence resulting in the busting of the complete project.

Developed CDF methodology facilitates two-way replication / consolidation technique which is quite helpful in the scenario mentioned above and can save the entire project without any additional cost and not jeopardizing the development scheme. This technique can save not only human resources and extra efforts but can also be helpful to overcome financial constraints of the project.

Developed CDF technique also provides true incremental backup facility which is capable of exporting only the changed data instead of entire table. The above developed technique is applicable in two-way homogeneous and one-way heterogeneous database environment which is a key feature of CDF.

IX. RECOMMENDATIONS

After complete implementation and evaluation of developed CDF methodology using two-way replication, following deficiencies are identified and can be enhanced in future work:

1. A GUI interface is required to handle all the setup activities for deploying CDF methodology on client and master side database servers. This will expedite the setup process as well as execution processes.

2. The developed methodology at this instance only supports homogeneous two-way data replication. It can be extended to support heterogeneity and n-way data replication types.

3. The CDF file can only capture DML operations. In case of DDL or DCL operation the CDF approach cannot be feasible at all.

4. The critical security issue of CDF file is that it contains textual data which can be altered by other sources. The textual data needs to be encrypted by using public / private key cryptography.

REFERENCES

[1] Alexander Thomson; Thaddeus Diamond; Shu-Chun Weng; Kun Ren; Philip Shao; *Daniel J.Abadi; Calvin, "Fast Distributed Transactions for Partitioned Database Systems*" ,SIGMOD '12, pp.1-12, 2012.

[2] A. Wang; P.L. Reiher; R. Bagrodia, "*A simulation evaluation of optimistic replicated filling in mobile environments*" Proceedings of International Performance, Computing and Communications Scottsdale, AZ, USA, pp. 43-51, 1999.

[3] Khan. F., Bashir, F. (2012). *Dual Head Clustering Scheme in Wireless Sensor Networks*. in the IEEE International Conference on Emerging Technologies (pp. 1-8). Islamabad: IEEE Islamabad.

[4] Syed Roohullah Jan, Khan. F., Zaman. A., (2015) *The Perception of students about Mobile Learning at University Level*. in the khgresearch.org NO. CONTENTS PAGE NO Turkey, pp.97

[5] Khan. F., Nakagawa. K. (2012). *Cooperative Spectrum Sensing Techniques in Cognitive Radio Networks*. in the Institute of Electronics, Information and Communication Engineers (IEICE), Japan , Vol -1, 2.

[6] Puthal, D., Nepal, S., Ranjan, R., & Chen, J. (2015). *A Dynamic Key Length Based Approach for Real-Time Security Verification of Big Sensing Data Stream.* In Web Information Systems Engineering–WISE 2015 (pp. 93-108). Springer International Publishing.

[7] M. A. Jan, P. Nanda, X. He, Z. Tan and R. P. Liu, "*A robust authentication scheme for observing resources in the internet of things environment*" in 13th International Conference on Trust, Security and Privacy in Computing and Communications (TrustCom), pp. 205-211, 2014, IEEE.

[8] Bettina Kemme; Gustavo Alonso, "*Don't Database Replication*", Proceeding of 26th VLDB Conference, Cairo, Egypt, 2000.

[9] Bipin Pokharel, "*Power Shortage, its impacts and the Hydropower Sustainability*", NRSC 616 Project Paper, 2010.

[10] Khan. F., Nakagawa, K. (2012). Performance Improvement in Cognitive Radio Sensor Networks. in the Institute of Electronics, Information and Communication Engineers (IEICE) , 8.

[11] Puthal, D., Nepal, S., Ranjan, R., & Chen, J.

(2015, August). *DPBSV--An Efficient and Secure Scheme for Big Sensing Data Stream.* InTrustcom/BigDataSE/ISPA, 2015 IEEE (Vol. 1, pp. 246-253). IEEE.

[12] M. A. Jan, P. Nanda and X. He, "*Energy Evaluation Model for an Improved Centralized Clustering Hierarchical Algorithm in WSN*," in Wired/Wireless Internet Communication, Lecture Notes in Computer Science, pp. 154–167, Springer, Berlin, Germany, 2013.

[13] B. Walker; G. Popek; R. English; C. Kline; G. Thiel, "*The LOCUS distributed operating system*"

a. Operating Systems Review, vol.17, (no.5, spec. issue) pp.49-70, 1983.

[14] D.B. Terry; M.M. Theimer; K. Petersen; A.J. Demers; M.J. Spreitzer; C.H. Hauser, "*Managing update conflicts in Bayou, a weekly connected replicated storage system,*" Operating Systems Review, Vol. 29, (no.5), pp.172-83, Dec. 1995.

[15] Khan. F., Kamal, S. A. (2013). *Fairness Improvement in long-chain Multi-hop Wireless Adhoc Networks*. International Conference on Connected Vehicles & Expo (pp. 1-8). Las Vegas: IEEE Las Vegas, USA.

[16] Puthal, D., Nepal, S., Ranjan, R., & Chen, J. (2016). *A dynamic prime number based efficient security mechanism for big sensing data streams*. Journal of Computer and System Sciences.

[17] M. A. Jan, P. Nanda, X. He and R. P. Liu, "Enhancing lifetime and quality of data in cluster-based hierarchical routing protocol for wireless sensor network", 2013 IEEE International Conference on High Performance Computing and Communications & 2013 IEEE International Conference on Embedded and Ubiquitous Computing (HPCC & EUC), pp. 1400-1407, 2013.

[18] Jabeen. Q., Khan. F., Khan, Shahzad, Jan. M. A., Khan. S.A (2016). Performance Improvement in Multihop Wireless Mobile Adhoc Networks. in the Journal Applied, Environmental, and Biological Sciences (JAEBS), Print ISSN: 2090-4274 Online ISSN: 2090-4215

[19] Bettina Kemme; Gustavo Alonso "Database Replication: a Tale of Research across Communities" *VLDB Endowment*, Vol. 3, No. 1, 2010.

[20] David Ratner; Peter Reiher; Gerald J. Popek

a. "ROAM: A Scalable Replication System for Mobility" Computer Science Department, UCLA, Los Angeles, CA 90095**.**

[21] Khan. F., Nakagawa, K. (2013). Comparative Study of Spectrum Sensing Techniques in Cognitive Radio Networks. in IEEE World Congress on Communication and Information Technologies (p. 8). Tunisia: IEEE Tunisia.

[22] Puthal, D., Sahoo, B., & Sahoo, B. P. S. (2012). *Effective Machine to Machine Communications in Smart Grid Networks*. ARPN J. Syst. Softw.© 2009-2011 AJSS Journal, 2(1), 18-22.

[23] Khan. F., (2014). *Secure Communication and Routing Architecture in Wireless Sensor Networks*. the 3rd Global Conference on Consumer Electronics (GCCE) (p. 4). Tokyo, Japan: IEEE Tokyo.

[24] M. A. Jan, P. Nanda, X. He and R. P. Liu, "*PASCCC: Priority-based application-specific congestion control clustering protocol*" Computer Networks, Vol. 74, PP-92-102, 2014.

[25] Farah Habib Chan chary; Saimul Islam, "*Data Migration: Connecting Databases in the Cloud*",

a. ICCIT, pp. 450-55, 2012.

[26] Filip; I. Vasar; R. Robu, "*Considerations about an Oracle Database Multi-Master Replication", Applied Computational Intelligence and Informatics*, SACI '09, pp. 147-152, 2009.

[27] Khan. F., (2014). *Fairness and throughput improvement in mobile ad hoc networks*. in the 27th Annual Canadian Conference on Electrical and Computer Engineering (p. 6). Toronto, Canada: IEEE Toronto.

[28] Mian Ahmad Jan and Muhammad Khan, "*A Survey of Cluster-based Hierarchical Routing Protocols*", in IRACST–International Journal of Computer Networks and Wireless Communications (IJCNWC), Vol.3, April. 2013, pp.138-143.

[29] Khan. S., Khan. F., (2015). *Delay and Throughput Improvement in Wireless Sensor and Actor Networks*. 5th National Symposium on Information Technology: Towards New Smart World (NSITNSW) (pp. 1-8). Riyadh: IEEE Riyad Chapter.

[30] G.H. Kuenning; R. Bagrodia; R.G. Guy; G.J. Popek; P. Reiher; A. Wang "*Measuring the quality*

a. *of service of optimistic replication," Proceedings, Object-Oriented Technology*. ECOOP'98 Workshop Reader, Brussels, Belgium, pp.319-20, 1998.

[31] Khan. Shahzad, Khan. F., Jabeen. Q., Arif F., Jan. M. A., Khan. S.A (2016). *Performance Improvement in Wireless Sensor and Actor Networks*. in the Journal Applied, Environmental, and Biological Sciences Print ISSN: 2090-4274 Online ISSN: 2090-4215

[32] Puthal, D., & Sahoo, B. (2012). *Secure Data Collection & Critical Data Transmission in Mobile Sink WSN:* Secure and Energy efficient

data collection technique.

[33] Mian Ahmad Jan and Muhammad Khan, "*Denial of Service Attacks and Their Countermeasures in WSN"*, in IRACST–International Journal of Computer Networks and Wireless Communications (IJCNWC), Vol.3, April. 2013.

[34] Qamar Jabeen, Khan. F., Muhammad Nouman Hayat, Haroon Khan, Syed Roohullah Jan, Farman Ullah, " *A Survey: Embedded Systems Supporting By Different Operating Systems*", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Print ISSN : 2395-1990, Online ISSN : 2394-4099, Volume 2 Issue 2, pp.664-673, March-April 2016. URL : http://ijsrset.com/IJSRSET1622208.php

[35] Guoqiong Liao, "*Data Synchronization and Resynchronization for Heterogeneous Databases*
a. *Replication in Middleware–based Architecture*", Journal of Networks, pp. 210-17, 2012.

[36] Hakik Paci; Elinda Kajo; Igli Tafa; Aleksander Xhuvani, "*Adding a new site in an existing oracle multi-master replication without Quiescing the Replication"*, International Journal of Database Management Systems (IJDMS), Vol.3, No.3, August 2011.

[37] William D. Norcott; john Galanes "*Method and apparatus for Chang data capture in database system*" USA Feb.14, 2006.

[38] J. J. Kistler and M. Satyanarayanan, "*Disconnected operation in the Coda File System*," ACM Transactions on Computer Systems, vol.10, (no.1), pp.3-25, Feb 1992.

[39] Matthias Wiesmann; Fernando Pedone; Andr´e Schiper; Bettina Kemme, "*Database replication Techniques: a Three Parameter Classification*" in 19th IEEE Symposium on Reliable Distributed System, pp. 206-215, 2001.

[40] M. J. Carey and M. Livny, "*Conflict detection tradeoffs for replicated data*," ACM Transactions on Database Systems, vol.16, (no.4), p.703-46, Dec. 1991.

[41] M. J. Fischer and A. Michael. "Sacrificing Serializability To Attain High Availability of Data In an Unreliable Network," Proceedings of the 4th Symposium on Principles of Database Systems, 1982.

[42] Richard A; Golding; Darrell D; E. Long" Quorum-oriented Multicast protocols for Data Replication" Santa Cruz, CA 95064 IEEE 1992.

[43] M. A. Jan, P. Nanda, X. He and R. P. Liu, "A Sybil Attack Detection Scheme for a Centralized Clustering-based Hierarchical Network" in Trustcom/BigDataSE/ISPA, Vol.1, PP-318-325, 2015, IEEE.

[44] Syed Roohullah Jan, Syed Tauhid Ullah Shah, Zia Ullah Johar, Yasin Shah, Khan. F., "*An Innovative Approach to Investigate Various Software Testing Techniques and Strategies*", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Print ISSN : 2395-1990, Online ISSN : 2394-4099, Volume 2 Issue 2, pp.682-689, March-April 2016. URL : http://ijsrset.com/IJSRSET1622210.php

[45] Khan. F., Khan. F., Jabeen. Q., Syed Roohullah Jan. R., Khan. S., (2016) *Applications, Limitations, and Improvements in Visible Light Communication Systems* in the VAWKUM Transaction on Computer Science Vol. 9, Iss.2, DOI: http://dx.doi.org/10.21015/vtcs.v9i2.398

[46] Qun Li; Honglin Xu, "*Research on the Backup Mechanism of Oracle Database*", International
a. Conference on Environmental Science and Information Application Technology, ESIAT'09, pp. 423-426, 2009.

[47] Syed Roohullah Jan, Khan. F., Muhammad Tahir, Shahzad Khan., (2016) "*Survey: Dealing Non-Functional Requirements At Architecture Level*", VFAST Transactions on Software Engineering, (Accepted 2016)

[48] M. A. Jan, "*Energy-efficient routing and secure communication in wireless sensor networks*," Ph.D. dissertation, 2016.

[49] Randall G. Bello; Karl Dias; Alan Downing; James Feenan; Jim Finnerty; William D. Norcott;
a. Harry Sun; Andrew Witkowski; Mohamed Ziauddin, *"Materialized Views in Oracle", Proceedings of the 24th VLDB Conference New York*, USA, 2008.

[50] Syed Roohullah Jan, Faheem Dad, Nouman Amin, Abdul Hameed, Syed Saad Ali Shah, " *Issues In Global Software Development (Communication, Coordination and Trust) - A Critical Review*", International Journal of Scientific Research in Science, Engineering and Technology(IJSRSET), Print ISSN : 2395-1990, Online ISSN : 2394-4099, Volume 2 Issue 2, pp.660-663, March-April 2016. URL : http://ijsrset.com/IJSRSET1622207.php

[51] Azim. N., Majid. A., Khan. F., Tahir. M., Safdar. M., Jabeen. Q., (2016) *Routing of Mobile Hosts in Adhoc Networks*. in the International Journal of Emerging Technology in Computer Science and Electronics (in press)

[52] Azim. N., Qureshi. Y., Khan. F., Tahir. M., Syed Roohullah Jan, Majid. A., (2016) *Offsite One Way Data Replication towards Improving Data Refresh Performance*. in the International Journal of Computer Science and Telecommunications (in press)

[53] Azim. N., Majid. A., Khan. F., Tahir. M., Syed Roohullah Jan, (2016) *People Factors in Agile Software Development and Project Management*. in the International Journal of Emerging Technology in Computer Science and Electronics (in press)

[54] Azim. N., Ahmad. I., Khan. F., Tahir. M., Majid. A., Syed Roohullah Jan, (2016) A New Robust Video Watermarking Technique Using H.264/AAC Codec Luma Components Based On DCT. in the International Journal of Advance Research and Innovative Ideas in Education (in press)

[55] Syed Roohullah Jan, Ullah. F., Khan. F., Azim. N, Tahir. M. (2016) Using CoAP protocol for Resource Observation in IoT. in the International Journal of Engineering Technology and Applications (in press)

[56] Syed Roohullah Jan, Ullah. F., Khan. F., Azim. N, Tahir. M,Safdar, Shahzad. (2016) Applications and Challenges Faced by Internet of Things- A Survey. in the International Journal of Emerging Technology in Computer Science and Electronics (in press)

[57] Tahir. M., Syed Roohullah Jan, Khan. F., Jabeen. Q., Azim. N., Ullah. F., (2016) EEC: Evaluation of Energy Consumption in Wireless Sensor Networks. in the International Journal of Engineering Technology and Applications (in press)

[58] Tahir. M., Syed Roohullah Jan, Azim. N., Khan. F., Khan. I. A., (2016) Recommender System on Structured Data. in the International Journal of Advance Research and Innovative Ideas in Education (in press)

[59] Tahir. M., Khan. F., Syed Roohullah Jan, Khan. I. A., Azim, N., (2016) Inter-Relationship between Energy Efficient Routing and Secure Communication in WSN. in the International Journal of Emerging Technology in Computer Science and Electronics (in press)

[60] Safdar. M., Khan. I. A., Khan. F., Syed Roohullah Jan, Ullah. F., (2016) Comparative study of routing protocols in Mobile adhoc networks. in the International Journal of Computer Science and Telecommunications (in press)

[61] M. A. Jan, P. Nanda, M. Usman and X. He. 2016. *PAWN: A Payload-based mutual Authentication scheme for Wireless Sensor Networks*, in 15th IEEE International Conference on Trust, Security and Privacy in Computing and Communications (IEEE TrustCom-16), "accepted".

[62] M. Usman, M. A. Jan and X. He. 2016. *Cryptography-based Secure Data Storage and Sharing Using HEVC and Public Clouds, Elsevier Information sciences*, "accepted".

[63] M. A. Jan, P. Nanda, X. He and R. P. Liu. 2016. *A Lightweight Mutual Authentication Scheme for IoT Objects*, IEEE Transactions on Dependable and Secure Computing (TDSC), "Submitted".

[64] M. A. Jan, P. Nanda, X. He and R. P. Liu. 2016. *A Sybil Attack Detection Scheme for a Forest Wildfire Monitoring Application*, Elsevier Future Generation Computer Systems (FGCS), "Submitted".

[65] Hayat, M., & Tahir, M. (2015). *PSOFuzzySVM-TMH: identification of transmembrane helix segments using ensemble feature space by incorporated fuzzy support vector machine. Molecular BioSystems*, *11*(8), 2255-2262.