http://www.icact.org/journal.asp

ICACT-TACT JOURNAL

Transactions on Advanced Communications Technology

Volume 6 Issue 3, May. 2017, ISSN: 2288-0003

Editor-in-Chief
Prof. Thomas Byeongnam YOON, PhD.

Global IT
Research Institute

Journal Editorial Board

Editor Guide

■ Introduction for Editor or Reviewer

All the editor group members are to be assigned as a evaluator(editor or reviewer) to submitted journal papers at the discretion of the Editor-in-Chief. It will be informed by eMail with a Member Login ID and Password.

Once logined the Website via the Member Login menu in left as a evaluator, you can find out the paper assigned to you. You can evaluate it there. All the results of the evaluation are supposed to be shown in the Author Homepage in the real time manner. You can also enter the Author Homepage assigned to you by the Paper ID and the author's eMail address shown in your Evaluation Webpage. In the Author Homepage, you can communicate each other efficiently under the peer review policy. Please don't miss it!

All the editor group members are supposed to be candidates of a part of the editorial board, depending on their contribution which comes from history of ICACT TACT as an active evaluator. Because the main contribution comes from sincere paper reviewing role.

■ Role of the Editor

The editor's primary responsibilities are to conduct the peer review process, and check the final camera-ready manuscripts for any technical, grammatical or typographical errors.

As a member of the editorial board of the publication, the editor is responsible for ensuring that the publication maintains the highest quality while adhering to the publication policies and procedures of the ICACT TACT(Transactions on the Advanced Communications Technology).

For each paper that the editor-in-chief gets assigned, the Secretariat of ICACT Journal will send the editor an eMail requesting the review process of the paper.

The editor is responsible to make a decision on an "accept", "reject", or "revision" to the Editor-in-Chief via the Evaluation Webpage that can be shown in the Author Homepage also.

■ Deadlines for Regular Review

Editor-in-Chief will assign a evalaution group(a Editor and 2 reviewers) in a week upon receiving a completed Journal paper submission. Evaluators are given 2 weeks to review the paper. Editors are given a week to submit a recommendation to the Editor-in-Chief via the evaluation Webpage, once all or enough of the reviews have come in. In revision case, authors have a maximum of a month to submit their revised manuscripts. The deadlines for the regular review process are as follows:

Evalution Procedure	Deadline
Selection of Evaluation Group	1 week
Review processing	2 weeks
Editor's recommendation	1 week
Final Decision Noticing	1 week

■ Making Decisions on Manuscript

Editor will make a decision on the disposition of the manuscript, based on remarks of the reviewers. The editor's recommendation must be well justified and explained in detail. In cases where the revision is requested, these should be clearly indicated and explained. The editor must then promptly convey this decision to the author. The author may contact the editor if instructions regarding amendments to the manuscript are unclear. All these actions could be done via the evaluation system in this Website. The guidelines of decisions for publication are as follows:

Decision	Description
Accept	An accept decision means that an editor is accepting the paper with no further modifications. The paper will not be seen again by the editor or by the reviewers.
Reject	The manuscript is not suitable for the ICACT TACT publication.
Revision	The paper is conditionally accepted with some requirements. A revision means that the paper should go back to the original reviewers for a second round of reviews. We strongly discourage editors from making a decision based on their own review of the manuscript if a revision had been previously required.

■ Role of the Reviewer

Reviewer Webpage:

Once logined the Member Login menu in left, you can find out papers assigned to you. You can also login the Author Homepage assigned to you with the paper ID and author's eMail address. In there you can communicate each other via a Communication Channel Box.

Quick Review Required:

You are given 2 weeks for the first round of review and 1 week for the second round of review. You must agree that time is so important for the rapidly changing IT technologies and applications trend. Please respect the deadline. Authors undoubtedly appreciate your quick review.

Anonymity:

Do not identify yourself or your organization within the review text.

Review:

Reviewer will perform the paper review based on the main criteria provided below. Please provide detailed public comments for each criterion, also available to the author.

- How this manuscript advances this field of research and/or contributes something new to the literature?
- Relevance of this manuscript to the readers of TACT?
- Is the manuscript technically sound?
- Is the paper clearly written and well organized?
- Are all figures and tables appropriately provided and are their resolution good quality?
- Does the introduction state the objectives of the manuscript encouraging the reader to read on?
- Are the references relevant and complete?

Supply missing references:

Please supply any information that you think will be useful to the author in revision for enhancing quality of the paperor for convincing him/her of the mistakes.

Review Comments:

If you find any already known results related to the manuscript, please give references to earlier papers which contain these or similar results. If the reasoning is incorrect or ambiguous, please indicate specifically where and why. If you would like to suggest that the paper be rewritten, give specific suggestions regarding which parts of the paper should be deleted, added or modified, and please indicate how.

Journal Procedure

Dear Author,

- **You can see all your paper information & progress.**

- **Step 1. Journal Full Paper Submission**

Using the Submit button, submit your journal paper through ICACT Website, then you will get new paper ID of your journal, and send your journal Paper ID to the Secretariat@icact.org for the review and editorial processing. Once you got your Journal paper ID, never submit again! Journal Paper/CRF Template

- **Step 2. Full Paper Review**

Using the evaluation system in the ICACT Website, the editor, reviewer and author can communicate each other for the good quality publication. It may take about 1 month.

- **Step 3. Acceptance Notification**

It officially informs acceptance, revision, or reject of submitted full paper after the full paper review process.

Status	Action
Acceptance	Go to next Step.
Revision	Re-submit Full Paper within 1 month after Revision Notification.
Reject	Drop everything.

- **Step 4. Payment Registration**

So far it's free of charge in case of the journal promotion paper from the registered ICACT conference paper! But you have to regist it, because you need your Journal Paper Registration ID for submission of the final CRF manuscripts in the next step's process. Once you get your Registration ID, send it to Secretariat@icact.org for further process.

- **Step 5. Camera Ready Form (CRF) Manuscripts Submission**

After you have received the confirmation notice from secretariat of ICACT, and then you are allowed to submit the final CRF manuscripts in PDF file form, the full paper and the Copyright Transfer Agreement. Journal Paper Template, Copyright Form Template, BioAbstract Template,

Journal Submission Guide

All the Out-Standing ICACT conference papers have been invited to this "ICACT Transactions on the Advanced Communications Technology" Journal, and also welcome all the authors whose conference paper has been accepted by the ICACT Technical Program Committee, if you could extend new contents at least 30% more than pure content of your conference paper. Journal paper must be followed to ensure full compliance with the IEEE Journal Template Form attached on this page.

➢ How to submit your Journal paper and check the progress?

Step 1. Submit	Using the Submit button, submit your journal paper through ICACT Website, then you will get new paper ID of your journal, and send your journal Paper ID to the Secretariat@icact.org for the review and editorial processing. Once you got your Journal paper ID, never submit again! Using the Update button, you can change any information of journal paper related or upload new full journal paper.
Step 2. Confirm	Secretariat is supposed to confirm all the necessary conditions of your journal paper to make it ready to review. In case of promotion from the conference paper to Journal paper, send us all the .DOC(or Latex) files of your ICACT conference paper and journal paper to evaluate the difference of the pure contents in between at least 30% more to avoid the self replication violation under scrutiny. The pure content does not include any reference list, acknowledgement, Appendix and author biography information.
Step 3. Review	Upon completing the confirmation, it gets started the review process thru the Editor & Reviewer Guideline. Whenever you visit the Author Homepage, you can check the progress status of your paper there from start to end like this, " Confirm OK! -> Gets started the review process -> ...", in the Review Status column. Please don't miss it!

Volume. 6 Issue. 3

Capacity-aware Key Partitioning Scheme for Heterogeneous Big Data Analytic Engines

Muhammad Hanif, Choonhwa Lee

Division of Computer Science and Engineering, Hanyang University, Seoul, Republic of Korea

honeykhan@hanyang.ac.kr , lee@hanyang.ac.kr

***Abstract*—Big data and cloud computing became the centre of interest for the past decade. With the increase of data size and different cloud application, the idea of big data analytics become very popular both in industry and academia. The research communities in industry and academia never stopped trying to come up with the fast, robust, and fault tolerant analytic engines. MapReduce becomes one of the popular big data analytic engine over the past few years. Hadoop is a standard implementation of MapReduce framework for running data-intensive applications on the clusters of commodity servers. By thoroughly studying the framework we find out that the shuffle phase, all-to-all input data fetching phase in reduce task significantly affect the application performance. There is a problem of variance in both the intermediate key's frequencies and their distribution among data nodes throughout the cluster in Hadoop's MapReduce system. This variance in system causes network overhead which leads to unfairness on the reduce input among different data nodes in the cluster. Because of the above problems, applications experience performance degradation due to shuffle phase of MapReduce applications. We develop a new novel algorithm; unlike previous systems our algorithm considers each node's capabilities as heuristics to decide a better available trade-off for the locality and fairness in the system. By comparing with the default Hadoop's partitioning algorithm and Leen partitioning algorithm: a). In case of 2 million key-value pairs to process, on the average our approach achieve better resource utilization by about 19%, and 9%, in that order; b). In case of 3 million key-value pairs to process, our approach achieve near optimal resource utilization by about 15%, and 7%, respectively.**

***Keyword*—Cloud and Distributed Computing, Context-aware Partitioning, Hadoop MapReduce, Heterogeneous Systems**

I. INTRODUCTION

BIG DATA [1] is getting bigger day by day with the information coming from instrumented, steady supply chains transmitting real-time data about the variabilities in everything from e-trading to weather. Furthermore, cautious information has in full swing through amorphous digital channels like social media, smart phones applications and different IoT devices. This big amount of data has challenges involve with it: data is big, it is fast, unstructured, has enormous amount of sources, and contains graphics. Cloud computing [2] becomes the interest point for both industry and academia due to its scalable, distributed and fault tolerant storage services and applications which have the aptitude to handle the challenges associated with big data. The data processing of big data in cloud and distributed computing environment is one of the core delinquents and under the spot light in research community for a while. MapReduce has proven to be the most popular implementation of computational processing framework which has the capability of supporting distributed storage holding large scale data over the distributed infrastructure like cloud computing.

Google's MapReduce [3] programming model is an emerging data intensive programming model for large scale data parallel applications including data mining, web indexing, multilinear subspace learning, business intelligence, and scientific simulations. MapReduce facilitates users with an easy parallel programming interface in distributed computing paradigm. It is used for distributed fault tolerance for supervision of multiple processing nodes in the clusters. One of the most significant feature of MapReduce is its high scalability that permits users to process massive amount of data in short time. There are numerous fields that benefit from MapReduce including bioinformatics [4], scientific analysis [5], web data analytics, security [6], and machine learning [7]. Hadoop [8] [9]is a standard open-source implementation of Google's MapReduce programming model for processing large amount of data in parallel. Hadoop was developed predominantly by Yahoo; where it processes petabyte scale data on tens of thousands of nodes [10] [11], and has been successfully adopted by several companies including Amazon, AOL, Facebook, and New York Times. For example, AOL uses it for running behavioural pattern analytics application which analyses the behavioural pattern of their users so as to targeted services on the basis of their location, interest and so on.

The Hadoop system runs on top of the Hadoop Distributed File System [12], within which data is loaded, partitioned into splits, and each split replicated across multiple nodes. Data processing is co-located with data storage: when a file needs to be processed, the Resource Manager consults a storage

Manuscript received April 26, 2017. This research work is follow-up of the invited journal to an accepted eminent conference paper of the 18th International Conference on Advance Communication Technology (ICACT2016). This work is supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (No. 2017R1A2B4010395).

Muhammad Hanif is with the Department of Computer and Software Engineering, Hanyang University, Wangsimni-ro 222, Seoul, Republic of Korea. (E-mail: honeykhan@ hanyang.ac.kr).

Choonhwa Lee is with the Division of Computer Science and Engineering, Hanyang University, Wangsimni-ro 222, Seoul, Republic of Korea. (Corresponding author, Phone: +82-2-2220-1268; fax: 82-2-2220-1723; e-mail: lee@ hanyang.ac.kr).

metadata service to get the host node for each split, and then system schedules a task on that node, so that data locality is exploited efficiently. The map task processes a data split into key/value pairs, on which hash partitioning function is performed, on the appearance of each intermediate key produced by any running map within the MapReduce system: *hash (Hash code (Intermediate-key) Modulo Reduce-ID)*
These hashing results are stored in memory buffers. In the reduce stage, a reducer takes a partition as input and performs the user defined reduce function on the partition. The storage distribution of the hash partition among the nodes affects the network traffic and the balance of the hash partition size play a significant role in the load-balancing among the reducer nodes.

This work scrutinizes the problem of variance in both the intermediate key's frequencies and their distribution among data nodes throughout the cluster in Hadoop's MapReduce system. This variance in system causes network overhead which leads to unfairness on the reduce input among different nodes in the cluster. Because of the above problems, applications experience performance degradation due to network overhead in the shuffle phase of MapReduce kind applications. The current Hadoop's default hash partitioning and Leen [13] partitioning work well in case of the uniform distribution of the data throughout the cluster in homogeneous systems. But in case of heterogeneous machines cluster, the system performance degrades due to the lack of consideration of heterogeneity of nodes and also the random-ness (non-uniform) in data distribution of data set throughout the cluster.

To alleviate the problems of partitioning and computation skew, we develop an algorithm which considers the node heterogeneity (i.e. the capacity of each node in the cluster) as heuristics to manage the data locality and fairness trade-off in the system by load-balancing according to the capabilities of nodes in the cluster. Our algorithm saves the network bandwidth overindulgence during the copying phase of intermediate data of MapReduce job along with balancing the reducers input. It improves the data locality in the individual nodes by decoupling mappers and reducer tasks, in this manner having more control on keys dissemination in each data node of the cluster.

Contribution of this work includes,

- Extension of node/locality/fairness-aware execution model for the partitioning scheme for Hadoop.
- A node-aware or capacity-aware algorithm to ascertain data locality and fair key distribution to achieve load-balancing in cluster according to the capabilities of nodes.
- Automatize the suboptimal trade-off between locality, load balancing, and fairness.
- Mitigate the partitioning and computation skew and achieve reduction in network overhead in the cluster in comparison to default state of the art partitioning schemes in heterogeneous environment.

The rest of the paper is organized as follows. Section 2 discusses the motivational background. Section 3 illuminates the system architecture, while the proposed scheme is discussed in section 4. The performance is evaluated in section 5. Section 6 discusses the related work and the paper is concluded in section 7.

II. Motivational Background

There are different aspects of the Hadoop scheduler which should be manipulated for the improvement of existing schedulers and mitigating the problem with those existing schedulers. Our main motivations of this work are some assumptions made by existing schedulers and situations where Hadoop's existing schedulers perform worse. In this section, we will justify our motivation of the work by going through the limitations of the previous state of the art approaches and demonstrating through motivational example by carrying out a series of experiments to validate the aforementioned problems in the current Hadoop implementation.

Hadoop's Limitations

Default Hadoop's system makes several implicit assumptions:

i. All nodes in the cluster can perform work at roughly the same rate i.e. the cluster is consist of Homogeneous machines.
ii. Tasks progress at a constant rate throughout time.
iii. A task's progress score is evocative of fraction of its total work that it has done. Specifically, in a reduce task, the copy, sort and reduce phases each take about 1/3 of the total time. Which is not the case in real life examples, i.e. jobs and tasks can be of different types such as CPU intensive, IO intensive, or Memory intensive.
iv. Tasks incline to finish in waves, so a task with a low progress score is likely a straggler.
v. Tasks in the same category (map or reduce) require roughly the same amount of work [3].

As we shall see, assumptions 1 and 2 break down in a virtualized data centre due to heterogeneity of the resources. Assumptions 3 and 4 can break down in a homogeneous data centre as well, and may cause Hadoop to perform poorly there too. In fact, Yahoo disables speculative execution on some jobs because it degrades performance, and monitors faulty machines through other means. Facebook disables speculation for reduce tasks in order to achieve better performance [14] [15]. Assumption 5 is intrinsic in the MapReduce paradigm, so we do not address it in this paper.

Leen's Limitations

Leen works well under some conditions and scenarios, while there are certain situations where Leen cannot work properly.

i. Leen assumption of uniform distribution of the keys throughout the cluster's nodes does not hold in most of the real world situations, as the real world input data set are usually distributed and non-uniform.
ii. It does not consider any heterogeneity, which is not the case in real world system. Almost all the data centres in the industry consists of heterogeneous machines such as Amazon EC2 [16], Microsoft Azure [17]
iii. It does not consider the numbers of keys throughout the cluster in calculation of the FLK, it just consider the locality on the basis of average numbers of keys i.e.

Nodes / Keys	PP	K1	K2	K3	K4	K5	K6	K7	K8	K9	Locality
Node1	X	12	9	8	4	17	2	1	3	0	23%
Node2	2X	24	17	5	5	3	0	1	8	1	37%
Node3	3X	17	28	19	14	13	5	3	5	1	33%

Fig. 1. Illustrate the current hash partitioning. The keys are ordered by appearance while each value represent the frequency of key in the data node.

Nodes / Keys	PP	K1	K2	K3	K4	K5	K6	K7	K8	K9	Locality
Node1	X	12	9	8	4	17	2	1	3	0	36%
Node2	2X	24	17	5	5	3	0	1	8	1	59%
Node3	3X	17	28	19	14	13	5	3	5	1	45%

Fig. 2. Using Leen partitioning scheme, it increases locality as compared to the default Hadoop's hash partitioning.

mathematical mean value of it.

a. This hurt the load-balancing in the system especially when best locality node is slower one.

The 2nd point of consideration of only homogeneous machines degrades the performance in both virtualized and non-virtualized situations. In a non-virtualized data centre, there may be multiple generations of hardware at the same data centre as in case of upgrading some system to the new generation whereas other remain intact. In a virtualized data centre where multiple virtual machines run on each physical host, such as Amazon EC2, co-location of VMs may cause heterogeneity. In EC2, co-located VMs use a host's full bandwidth when there is no contention and share bandwidth fairly when there is contention [16].

Motivational Example

As shown in Fig. 1, there are three nodes: Node1, Node2, and Node3, with nine intermediate keys, ordered by their influx during the map tasks execution. For the reference, we use a similar example of nine keys like Leen [13] algorithm and use it as a comparative example among the different partitioning schemes. The sum of the entire nine keys frequencies is 225 keys, distributed randomly in the cluster of three data nodes, which is usually the case in distributed infrastructure. Also the keys occurrences are wide-ranging along with the dispersal among the data nodes.

Fig. 1 shows that the key partitioning results using the default Hadoop Hash partitioning, which is assigning K1, K4, and K7 to Node1; K2, K5, and K8 to Node2; whereas K3, K6, and K9 to Node3. So despite the fact that Node3 has the highest processing capability, Node1 needs to process 81 out of 225, Node2 needs to process 103 out of 225, and finally Node3 needs to process 41 out of 225 key-value pairs leading to non-optimal utilization of the resources. This clarify that it is scant in case of the partitioning skew in terms of data size which needs to be shuffled through the system network and balance distribution of reducer's input. We discern that the data size needs to be transmitted through the network in the shuffle phase is enormous, and the hash partitioning is inadequate in the presence of partitioning skew. In this example, the percentages of keys locally partitioned on each of the three nodes are 23%, 37% and 33%, respectively. And the Total Network Traffic is 156 keys out of 225 keys. According to the processing power of the Nodes in the given example shown in the Table.1, Node1 process 81 keys-value pairs in 36 units of time, Node2 process its 103 key-value pairs in 23 units of time, and Node3 process its 41 assigned key-value pairs in 6 units of time, which prove the hypothesis of non-optimal utilization resources that Node3 stay idle for about 30 units of time (36 units for Node1 – 6 units for Node3). This kind of situation creates different problems like poor resource utilization and performance degradation especially in heterogeneous environment.

Leen [13], which is an improvement to the default hash partitioning of the Hadoop system, performs well in some situations, specifically, in case of homogeneous cluster. It performs worse in some situation because it does not consider the non-uniform distribution of data throughout the data nodes in the cluster, as well as does not take into account the heterogeneity of the nodes which is the case in most of the real world scenarios. Continuing the example above, Leen assigns K5, K6, and K7 to Node1; K1, K4, K8, and K9 to Node2; whereas K2, and K3 to Node3. Leading to the fact that Node1 needs to process 45 out of 225, Node2 needs to process 94 out of 225, and finally Node3 needs to process 86 out of 225 key-value pairs leading to a sub-optimal solution which is an enhanced assignment of key-value pairs than the one by default hash partitioning scheme. The percentage of keys locality in the three nodes are 36%, 59%, and 45%, respectively. The total network traffic is to transfer 150 keys out of 225 keys, which decreases the numbers of keys transfer over the network and leads to around 2% improvement over the hash partitioning as shown in Fig. 2. Bestowing to the previous calculations, Node1 process 45 keys-value pairs in 20 units of time, Node2 process its 94 key-value pairs in 21 units of time, and Node3 process its 86 assigned key-value

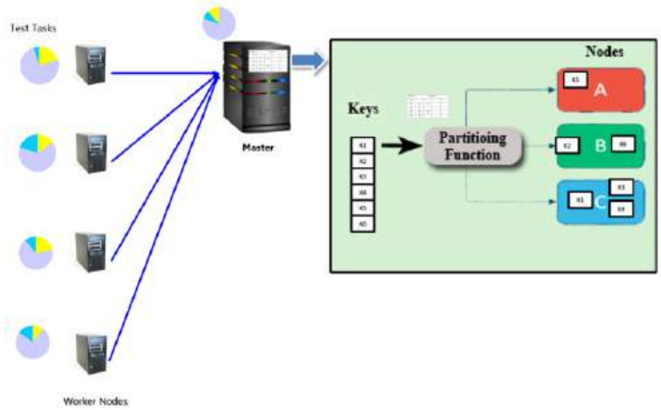


Fig. 3. Proposed scheme system architecture.

pairs in 13 units of time, in which case Node3 stay idle only for about 8 units of time instead of 30 units as in the case of default hash partitioning (i.e. 21 units for Node2 – 13 units for Node3). This example shows that the Leen partitioning algorithm help the system to improve the utilization of the whole cluster eventually.

By the above reasoning, we have to conclude that the previous work lack of contemplation of the capacity awareness of the nodes superintends any opportunities of the reduction of the network traffic during the shuffle phase of the MapReduce application execution, in case of heterogeneity in the cluster. Also the load misbalancing data distribution of reducer nodes occurs, i.e. 1). Nodes with higher capacity get less amount of data leading to non-optimal utilization of resources and under loading, 2). Lower capacity nodes getting more data to process leading to performance degradation, overloading, and straggler effect.

III. System Architecture

In this section, we will introduce the system architecture and how the proposed system work in the specified environment. As mentioned earlier, we decouple the mappers and reducers in order to achieve more parallelism and keep track of all the intermediate data keys frequencies and distribution in the form of capacity-keys frequency table. In order to meritoriously partition certain input data set of K keys distributed over N nodes in a cluster, the system need to find the best available solution in a space of K^N possible combinations. The system achieve it through the proposed approach which will be explained in the forthcoming section.

The system architecture is consists of a master node and a number of worker nodes as shown in the Fig. 3, and it works as subsequent way. The system first run some test tasks on the worker nodes over the cluster which send the results back to the master node. The master node uses the gather information of each worker node in the cluster and keep track of the execution time of each node in the cluster for the jobs run by the specified node. The master node then estimates the processing power ratio using the sample task run results. Then master node constructs node-capacity table which is further used in the edifice of capacity-keys frequency table. As the master node already knows the input keys data distribution over the cluster, the formation of capacity-keys frequency

TABLE I
EXAMPLE OF MEASURING HETEROGENEITY

Node	Execution Time	PP-Ratio	Optimal Keys Assignment
Node A	10	1	40%
Node B	20	2	30%
Node C	30	3	20%
Node D	40	4	10%

*Execution units used are seconds here.

table take place using the perceptibly known information required. Then this table is being forwarded to the task scheduler. The task scheduler schedule different keys to different node while taking all the available information into account, in order to get the sub-optimal trade-off between fairness, locality and load-balancing. And as a result of this procedure, every node in the cluster get the numbers of tasks and partitions of the input data suitable to their processing power.

IV. Proposed Approach

In this section, we will thoroughly explain the proposed approach in three different subsections. First, we will explain the details about how to measure the heterogeneity of different nodes exists within the cluster. Then will move to demonstrating the effectiveness of the proposed approach with the help of continuing the same example from section 2. Finally, the details of the mathematical model used in the system will be elucidated in the last subsection of this section.

We introduce a new metric NA-FLK, which consider the node heterogeneity in the cluster. There is always a trade-off between the locality and fairness in heterogeneous systems, so we use a weightage model where users can choose the ratio between the locality and fairness. By default the locality-fairness ratio will be 60% to 40% i.e. 60% weightage to locality while 40% weightage to fairness. For this we will use two new properties, <mapred.fairness.weightage> and <mapred.locality.weightage>. With these properties, we gives the administrator the power to decide which of the metric is more valuable to their organization according to their SLA with users.

A. Measuring Heterogeneity

Afore implementing our partitioning algorithm, we need to measure the heterogeneity of Hadoop cluster in terms of data processing speed. Such processing speed highly depends on data-intensive applications. Thus, heterogeneity measurements in the cluster may change while executing different MapReduce data processing applications. We introduce a metric "processing power ratio", to measure each node's processing speed in a heterogeneous cluster upon execution of new application execution, insertion of new node, or failure of node in the cluster. Processing power ratios are determined by a sketching procedure conceded out through following steps.

- The data processing operations of a given MapReduce application are separately carrying out in each node. To fairly compare processing speed, we guarantee that all the nodes process the same amount of input data. For example, experiment with the same size input file of 1GB to process by the specified node.

Nodes / Keys	PP	K1	K2	K3	K4	K5	K6	K7	K8	K9	Locality
Node1	X	12	9	8	4	17	2	1	3	0	2%
Node2	2X	24	17	5	5	3	0	1	8	1	59%
Node3	3X	17	28	19	14	13	5	3	5	1	60%

Fig. 4. Motivational Example: Using our Capacity-Aware partitioning scheme outperform both Hadoop's hash partitioning and Leen partitioning.

- The response time of each node performing the data processing operations will be recorded in an Array-List data structure.
- Shortest response time is used as a reference to normalize the response time measurements.
- The normalized processing powers ratios are employed by the partitioning algorithm of the system while taking decision of the trade-off between the fairness, load-balancing, and locality.

Measuring Heterogeneity Example: Suppose that there are four heterogeneous nodes: Node A, B, C and D, in a Hadoop MapReduce cluster as shown in table 1. After running a Hadoop application on each node, one collects the response time of the application on node A, B, C and D is 10, 20, 30 and 40 seconds, respectively. The response time of the application on node A is the shortest. Therefore, the processing power ratio of node A with respect to this application is set to 1, which becomes a reference used to determine processing power ratios of node B, C and D. Thus, the processing power ratios of node B, C and D are 2, 3 and 4, respectively. Recall that the processing power capacity of each node is quite stable with respect to any specified Hadoop analytic application. Hence, the processing power ratios are free of input file sizes. Table I shows the response times, processing power ratios, and optimal keys assignment percentage for each node in the cluster. As we can grasp, the optimal keys assignment percentage with the value of 40% for Node A is the highest, 30% for Node B, 20% for Node C, and 10% for Node D, so the scheduler with the suboptimal solution will get the nearest possible values for each node in the cluster leading to a load-balanced cluster.

B. Partitioning Example

Continuing with section 2-C motivational examples, where the total network traffic was high and the locality was lower than expected. Our proposed Capacity-aware scheme is very much appropriate for the practical scenarios because it cover most of the drawbacks of previously developed schemes. This scheme can work in case of diverse non-uniformly distributed data over the nodes, and also in case of heterogonous machines in the system. Continuing with the motivational example, as shown in Fig. 4, the proposed scheme NoLFA assigns K7 to Node1; K1, K4, K8, and K9 to Node2; whereas K2, K3, K5, and K6 to Node3. Prominently leading towards the datum that Node1 needs to process 5 out of 225, Node2 needs to process 94 out of 225, and Node3 needs to process 126 out of 225 key-value pairs, which give us a near-optimal solution of assignment of key-value pairs. The percentage of keys locality in the three nodes are 2%, 59%, and 60%, respectively. The total network traffic is to transfer 138 keys out of 225 keys, which decreases the numbers of keys transfer over the network and leads to around 8% improvement over the hash partitioning scheme. According to the processing power of the Nodes in the given example, Node1 process 5 keys-value pairs in 2 units of time, Node2 process its 94 key-value pairs in 21 units of time, and Node3 process its 126 assigned key-value pairs in 18 units of time. Thus, NoLFA achieves better load-balancing according to the capabilities of the nodes in the system.

C. Mathematical Model

Our proposed algorithm introduces heterogeneity awareness into the default Hadoop scheduling system by altering the hash key partitioning scheme while taking locality of data and fairness into account. For the effective partitioning of data set of K keys distributed over N nodes in cluster, there will be best possible solution in K^N solutions. To find suitable solution of all these possible ways, we use processing power or capabilities of nodes as heuristic in the proposed scheme. We keep in mind that for the best solution, we need to find a good trade-off between the locality of keys-value pairs, load-balancing, and fairness to the reduce nodes throughout the cluster. After estimating the processing power of the nodes, we need to find the optimal load for the reducers depending on the numbers of reducers according to the SLA based configuration of the cluster.

To calculate the suboptimal load for each reducer in the cluster, we need to use the optimal load percentage table with total data set,

$$OptimalLoadN_j^i = OptimalLoad_j * DataSetK$$

For the locality of keys in a specified node, we use the frequencies of keys partitioned to that node divided by the optimal load for the specified node (instead of just the athematic mean of all, which is wrong in most practical world applications).

$$Locality_j = \frac{\text{partitioned keys}}{OptimalLoadN_j^i}$$

As we can see in the above equation, the locality of each node j is the ration of partitioned keys to the Optimal Load from the already calculated table. The best locality node is usually the node which contains maximum frequencies of a key, and that key is partitioned to that node. The fairness in the system could be calculated as follows,

$$Fairness - S = \sqrt{\frac{\sum_{j=1}^{n}(FK_j^i - OptimalLoadN_j^i)^2}{Nos\ of\ Reducers}}$$

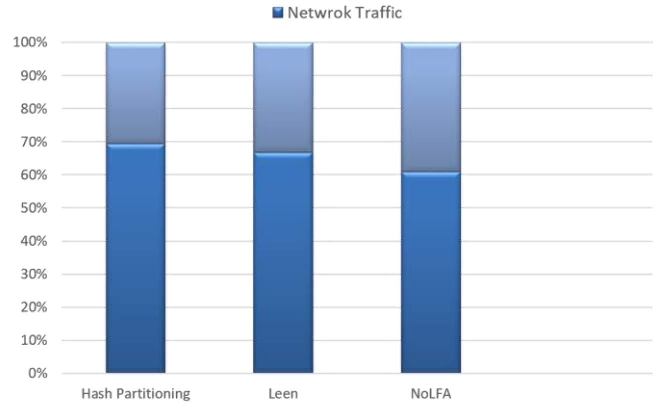


Fig. 5. Percentage of total network traffic generated in the cluster.

where FK_j^i points to the frequency of key K_i in the data node n_j, and $OptimalLoadN_j^i$ represents the optimal load on reducer according to their computing power. The best locality indicates partitioning K_i to the data node n_j which has the maximum frequencies for the key. The total network traffic in the cluster can be calculated as,

$$NW\ Traffic = \sum \left(TotalMapOutput_j * \left(1 - Locality_j\right)\right)$$

With this formula, we can get an educated guess of the network overhead in the cluster with the combined effect of both the total intermediate data and each node assessed locality.

V. PERFORMANCE EVALUATION

To evaluate the performance of the proposed algorithm, we have designed and execute certain set of experiments with different variations of keys and frequencies distribution. The experimental results shows that the our proposed approach NoLFA algorithm over-run Leen and Hash partitioning by decreasing the total network traffic in the cluster as shown in the Fig. 5. Hash partitioning is the default partitioning scheme of the Hadoop data processing framework, which on the average generates around 70% of the cluster's network traffic, whereas Leen improve it and crafts around 67% of network traffic in the cluster on the average. And our algorithm NoLFA outperforms both of the above partitioning scheme by achieving on average better results, and creates around 61% of the total network traffic. This is because of the fact that NoLFA considers the capacity of each machine/node in the cluster while taking the decision about the partitioning of different keys to different nodes in the cluster.

The second set of experiments focus on the load-balancing problem in the Hadoop scheduling systems. As Fig. 6 shows that the processing power of three different nodes, the desired optimal load-balancing for all three nodes, and the load balancing achieved by each partitioning scheme including hash partitioning, Leen, and NoLFA. From the domino effect, it is clear that there is a trade-off between load balancing and locality of key-values pairs throughout the Hadoop's cluster. So the outcome shows that the NoLFA perform better in selecting the trade-off between load balancing and locality because it considers the heterogeneity of nodes in cluster whereas others does not consider any such heuristics and assign on the basis of static decided values.

Through better load balancing ability of NoLFA using node computing power as heuristics, it attains decrease in the execution time of the overall application. Fig. 7 shows the normalized execution time of each partitioning scheme designed for this set of experiments i.e. Hadoop's default hash partitioning scheme, Leen, and NoLFA. For the normalization effect, we use NoLFA as base for the calculation. Leen is about 0.22X slower on average as compare to our algorithm whereas Hash partitioning takes approximately 0.6X times extra time as compare to our NoLFA partitioning algorithm's execution time. With the elucidation of Fig. 8, we illustrate the average resource utilization of cluster resources by Hadoop, Leen, and NoLFA, respectively. X-Axis shows different schemes such as Hadoop, Leen, and NoLFA. Y-Axis shows the average percentage of cluster resource utilization by different schemes. Whereas Z-Axis shows the change in the data size in units of numbers of key-values pairs processed in each case study. As we can surmise from Fig. 8, the blue bars at the front represents the state of affairs when the numbers of key-values pairs are 2 million. The red bars in the back represents the results in case of 3 million key-value pairs been processed by each scheme. We can deduct from these case studies that Leen and NoLFA keep the trend of outperforming the default Hadoop partitioning scheme in both cases, as the numbers of key-values pairs increased in the experiment. The utilization increases with the number of key-value pair increases until the saturation of data to the nodes in the cluster.

Finally, Fig. 9 signposts the network traffic overhead in all six instance of the experiments for the Hadoop with number of key-value pairs to process set to 2 million and three million;

Nodes	Processing Power	Estimated Optimal Load	Hash Load-Balance	Leen Load-Balance	NA-Leen Load-Balance
Node1	X	17%	36%	20%	2%
Node2	2X	33%	46%	42%	42%
Node3	3X	50%	18%	38%	56%

Fig. 6. Trade-off between Load balancing and Fairness.

Fig. 7. Normalized execution time with NoFLA as base for normalization.

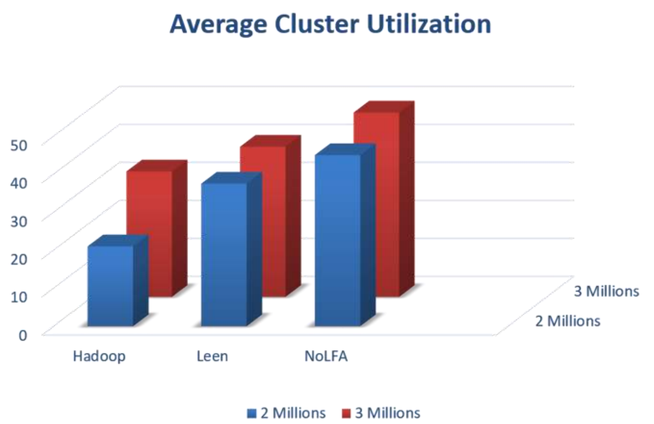


Fig. 8. Average performance gain of Hadoop, Leen, and NoLFA. Results are normalized according the number of key-value pairs processed by each scheme accordingly.

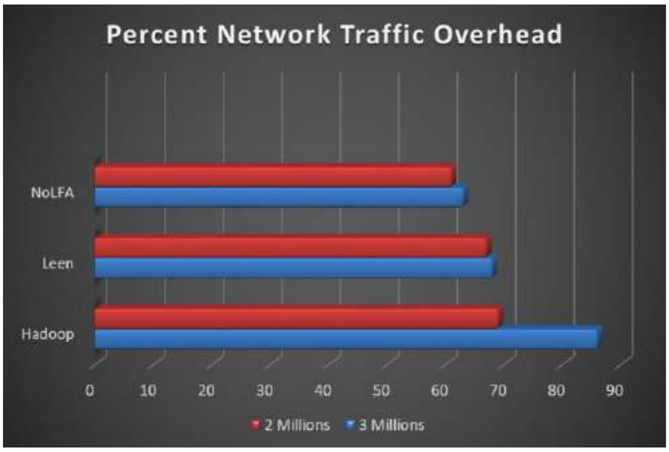


Fig. 9. Percent Network Traffic Overhead vs Numbers of Key-value pairs. The upper red bars shows the value for 2 million key-value pairs while the lower blue bar show it for 3 million key-value pairs to process.

for Leen with the number of key-value pairs set to 2 million and 3 million; and for NoLFA with the key-value pairs set to 2 million and 3 million, accordingly. X-axis shows the average percent network traffic overhead caused in each instance of experiment. Y-axis shows different partitioning techniques used in the model experiments. The top bottom blue bar shows the case when the number of key-values pairs to be processed is 3 million, whereas the top red bar represent the case of 2 million key-value pairs to be processed, accordingly. The results shows that the network overhead increases as the amount of data need to be processed increases in each instance of experiment.

With the above reasoning, we claim that it is clear that capacity awareness play an important role in selection of the partitioning different keys to different nodes in the cluster, and has a positive influence on the overall performance and near optimal utilization of the cluster.

VI. RELATED WORK

Previous work aiming to improve the performance of MapReduce system achieved the desired goal through various approaches including reduction of network cramming by inserting partial data awareness into the shuffle phase, skew mitigation, replica awareness, and network awareness.

Authors in [18] proposed two schemes of pre-fetching and pre-shuffling for communal MapReduce environments. Pre-fetching use data locality and assign tasks to nearest node to the data block, whereas pre-shuffling reduce network overhead of slouching the key-value pairs. Our scheme NoLFA decouple the mapper and reducer tasks and scan over the keys frequency table generated upon execution of map phase and cross reference it with the capacity table created after executing the sample jobs on the nodes in the cluster to achieve the goal of partial balanced reduce tasks throughout the cluster. ShuffleWatcher [19] proposed a multi-tenant Hadoop scheduler that tries to curtail the network traffic in shuffle phase while maintaining the particular fairness constraints of the system. The working principle of the ShuffleWatcher is on the basis of the following three steps. First, it limit the intra-job map shuffle according to the network traffic load. Second, it auspiciously apportion the map tasks to localize the intermediate data. Finally, it exploit the confined intermediate data and delayed shuffle to reduce the network traffic in shuffle phase by favorably scheduling reduce tasks in nodes crofting the intermediate data. Unlike ShuffleWatcher, NoLFA take the capacity information of each node in the cluster whereas distributing the tasks which is very helpful in case of the heterogeneity in the cluster. EC-Cache [20] introduced a load-balanced, low latency cluster cache via erasure coding to overawed the inadequacy of selective replication. It employs erasure coding through two principles. First, by splitting and erasure coding individual objects during writes. Second, late binding. These led to improving load-balancing in the system. Tang et al. proposed a sampling evaluation to solve the problems of partitioning skew and intermediate data locality for the reduce tasks called Minimum Transmission Cost Reduce Task Scheduler [21] (MTCRS). They used communication cost and waiting time of each reduce task as heuristic whereas deciding which task to assign to which node in the cluster. Their scheduling algorithm used Average Reservoir Sampling for the spawning of parameter sizes, and location of intermediate data partitions for their rummage-sale mathematical estimation model. On the other hand, NoLFA used Random Sampling.

Transferring data over the network is costly and causes performance degradation more severely in federated clusters. Kondikoppa et al. [22] introduced a network-aware scheduling algorithm for Hadoop system which work in federated clusters, improving the map tasks scheduling and consequently tries to abate the network traffic overhead leading to improved performance gain. NoLFA has different approach of decoupling the map and reduce tasks and routinize the keys-capacity frequency table to achieve the specified goal. Locality Aware Reduce Scheduling (LARS) [23] abate data transfer in their proposed grid-enabled MapReduce framework. Due to heterogeneity awareness of nodes in the grid, the map data size varies leading to assigning map tasks associated with different data size to different worker nodes according to their computation power. The LARS algorithm will select the nodes with largest region size of the intermediate data to be the destination for the reduce tasks. NoLFA achieve the desired goal with the frequency-capacity table.

Another concern is the partitioning skew that ascends due to an unstable distribution of map output across nodes, causing a massive size of data input for some reduce tasks while lesser for others. Centre-of-Gravity (CoG) [24] reduce scheduling add locality and skew cognizance to the scheduler. They allocates the reduce tasks to nodes nearer to nodes creating the intermediate data for that listed reduce tasks. SkewReduce [25] was proposed with the intention to dazed the computation skew in MapReduce systems where the partition run time depends on the data values as well as input size. It uses a user defined cost function based optimizer to regulate the partitioning parameterization of input data to curtail the computational skew. NoLFA only consider the case where the computational time of an input partition depends upon the input data size rather than both. LEEN [13] attenuates the partitioning skew and minimalize the transfer of data using network through load balancing of the data distribution among the nodes in the cluster. It also improve the data locality of MapReduce tasks in the process. Unlike LEEN, NoLFA work in heterogeneous environment as well through our capacity awareness algorithm. Chen el al. [26] proposed Dynamic Smart Speculative technique to alleviate the problems with default speculation implementation like skew, indecorous phase percentage configuration and asynchronous twitch of certain tasks with the cost of degradation of performance for batch jobs. Whereas FP-Hadoop [27] introduces a new phase called intermediate reduce (IR) to parallelize the reduce task to efficiently tackle the reduce data skew problem. IR process the blocks of intermediate data in parallel. NoLFA has a different approach of decoupling the mappers and reducers tasks as introduced in our previous work [28].

VII. Conclusion

Hadoop affords simplified implementation of MapReduce framework, but its design stances challenges to attain best performance in application execution due to tightly coupled shuffle, obstinate scheduling and partitioning skew. In this paper, we developed an algorithm which takes node capabilities as heuristics to achieve better trade-off between locality and fairness in the Hadoop MapReduce system. It effectively improves the data locality and by comparing with the default Hadoop's partitioning algorithm and Leen partitioning algorithm, on the average our approach achieves better performance gain and outperform both of the previously mentioned partitioning schemes.

Acknowledgment

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (No. 2017R1A2B4010395).

References

[1] M. James, M. Chui, B. Brown, J. Bughin, R. Dobbs, C. Roxburgh, and A. H. Byers, "Big data: The next frontier for innovation, competition, and productivity," *McKinsey Glob. Inst.*, no. June, p. 156, 2011.

[2] P. Mell and T. Grance, "The NIST definition of cloud computing," *NIST Spec. Publ.*, vol. 145, p. 7, 2011.

[3] J. Dean and S. Ghemawat, "MapReduce," *Commun. ACM*, vol. 51, no. 1, p. 107, 2008.

[4] A. Matsunaga, M. Tsugawa, and J. Fortes, "CloudBLAST: Combining MapReduce and Virtualization on Distributed Resources for Bioinformatics Applications," *2008 IEEE Fourth Int. Conf. eScience*, pp. 222–229, 2008.

[5] J. Ekanayake, H. Li, B. Zhang, T. Gunarathne, S. Bae, J. Qiu, and G. Fox, "Twister : A Runtime for Iterative MapReduce," *HPDC '10 Proc. 19th ACM Int. Symp. High Perform. Distrib. Comput.*, pp. 810–818, 2010.

[6] G. Mackey, S. Sehrish, J. Bent, J. Lopez, S. Habib, and J. Wang, "Introducing map-reduce to high end computing," *2008 3rd Petascale Data Storage Work.*, pp. 1–6, 2008.

[7] C.-T. Chu, S. K. Kim, Y.-A. Lin, Y. Yu, G. Bradski, A. Y. Ng, and K. Olukotun, "Map-Reduce for Machine Learning on Multicore," *Adv. Neural Inf. Process. Syst. 19*, pp. 281–288, 2007.

[8] Apache!, "Apache™ Hadoop!" [Online]. Available: http://hadoop.apache.org/. [Accessed: 19-Dec-2016].

[9] Amazon!, "Amazon Elastic Compute Cloud (EC2)." [Online]. Available: http://aws.amazon.com/ec2/. [Accessed: 19-Dec-2016].

[10] Yahoo!, "Yahoo Developer Network." [Online]. Available: https://developer.yahoo.com/blogs/hadoop/yahoo-launches-world-largest-hadoop-production-application-398.html. [Accessed: 1-Jan-2017].

[11] R. Jain, D. Chiu, and W. Hawe, "A Quantitative Measure of Fairness and Discrimination for Resource Allocation in Shared Computer Systems," *DEC technical report TR301*, vol. cs.NI/9809, no. DEC-TR-301. pp. 1–38, 1998.

[12] K. Shvachko, H. Kuang, S. Radia, and R. Chansler, "The Hadoop Distributed File System," *2010 IEEE 26th Symp. Mass Storage Syst. Technol.*, pp. 1–10, 2010.

[13] S. Ibrahim, H. Jin, L. Lu, S. Wu, B. He, and L. Qi, "LEEN: Locality/fairness-aware key partitioning for MapReduce in the cloud," *Proc. - 2nd IEEE Int. Conf. Cloud Comput. Technol. Sci. CloudCom 2010*, no. 2, pp. 17–24, 2010.

[14] T. Condie, N. Conway, P. Alvaro, J. M. Hellerstein, K. Elmeleegy, and R. Sears, "MapReduce online," *Nsdi'10*, pp. 21–21, 2010.

[15] M. Zaharia, A. Konwinski, A. Joseph, R. Katz, and I. Stoica, "Improving MapReduce Performance in Heterogeneous Environments." *Osdi*, pp. 29–42, 2008.

[16] "Amazon EC2 Instance Types." [Online]. Available: https://aws.amazon.com/ec2/instance-types/. [Accessed: 3-Jan-2017].

[17] T. Ristenpart, E. Tromer, H. Shacham, and S. Savage, "Hey, You, Get Off of My Cloud: Exploring Information Leakage in Third-Party Compute Clouds," *Proc. 16th ACM Conf. Comput. Commun. Secur*, pp. 199–212, 2009.

[18] S. Seo, I. Jang, K. Woo, I. Kim, J.-S. Kim, and S. Maeng, "HPMR: Prefetching and pre-shuffling in shared MapReduce computation environment," *2009 IEEE Int. Conf. Clust. Comput. Work*, pp. 1–8, 2009.

[19] F. Ahmad, S. T. Chakradhar, A. Raghunathan, and T. N. Vijaykumar, "ShuffleWatcher: Shuffle-aware Scheduling in Multi-tenant MapReduce Clusters," *2014 USENIX Annu. Tech. Conf. (USENIX ATC 14)*, pp. 1–13, 2014.

[20] K. V Rashmi, M. Chowdhury, J. Kosaian, I. Stoica, K. Ramchandran, and I. Osdi, "EC-Cache : Load-Balanced , Low-Latency Cluster Caching with Online Erasure Coding This paper is included in the Proceedings of the R / W," *Osdi*, 2016.

[21] X. Tang, L. Wang, and Z. Geng, “A Reduce Task Scheduler for MapReduce with Minimum Transmission Cost Based on Sampling Evaluation,” vol. 8, no. 1, pp. 1–10, 2015.
[22] P. Kondikoppa, C.-H. Chiu, C. Cui, L. Xue, and S.-J. Park, “Network-aware Scheduling of Mapreduce Framework on Distributed Clusters over High Speed Networks,” pp. 39–44, 2012.
[23] Y. L. Su, P. C. Chen, J. B. Chang, and C. K. Shieh, “Variable-sized map and locality-aware reduce on public-resource grids,” *Futur. Gener. Comput. Syst.*, vol. 27, no. 6, pp. 843–849, 2011.
[24] M. Hammoud, M. S. Rehman, and M. F. Sakr, “Center-of-gravity reduce task scheduling to lower MapReduce network traffic,” *Proc. - 2012 IEEE 5th Int. Conf. Cloud Comput. CLOUD 2012*, pp. 49–58, 2012.
[25] Y. Kwon, M. Balazinska, B. Howe, and J. Rolia, “Skew-Resistant Parallel Processing of Feature-Extracting Scientific User-Defined Functions,” 2010.
[26] Q. Chen, C. Liu, and Z. Xiao, “Improving MapReduce performance using smart speculative execution strategy,” *IEEE Trans. Comput.*, vol. 63, no. 4, pp. 954–967, 2014.
[27] M. Liroz-Gistau, R. Akbarinia, D. Agrawal, and P. Valduriez, “FP-Hadoop: Efficient processing of skewed MapReduce jobs,” *Inf. Syst.*, vol. 60, pp. 69–84, 2016.
[28] M. Hanif and C. Lee, “An Efficient Key Partitioning Scheme for Heterogeneous MapReduce Clusters,” *Proc. 18th IEEE Int. Conf. Adv. Commun. Technol.*, 2016.

Muhammad Hanif was born in Pakistan. He received his B.S. degrees in computer and software engineering from University of Engineering and Technology (UET), Peshawar, Pakistan in 2012. He is currently pursuing his MS leading to PhD degree in Computer Software Engineering at Hanyang University, Seoul, South Korea. His current research interest includes Cloud & Distributed Computing, Big Data Analytic Engines, Stream Processing Frameworks, and Distributed Scheduling.

Choonhwa Lee was born in South Korea. He has been with the Division of Computer Science and Engineering at Hanyang University, Seoul, South Korea since 2004, and currently as Professor. He received his B.S. and M.S. degrees in computer engineering from Seoul National University (SNU), South Korea, in 1990 and 1992, respectively, and his Ph.D. degree in computer engineering from the University of Florida, Gainesville, in 2003. He worked as senior research engineer at LGIC Ltd from 1992 to 1998. He is a member of IEEE since 2004. His research interests include cloud computing, peer-to-peer and mobile networking and computing, and services computing technology.

Radio access and Transmission models for universal service

Idriss Saleh BACHAR*, Ahmed Dooguy KORA**, Roger Marcelin FAYE***, Christelle Aupetit-Berthelemot****

* *Autorité de Régulation des Communications Electroniques et Postes, BP 5808, Ndjamena, TCHAD*

***École Supérieure Multinationale des Télécommunications, BP 10000, Dakar, SENEGAL*

**** École Supérieure Polytechnique, BP 5085, Dakar-Fann, SENEGAL*

***** Xlim/SRI/Resyst, UMR-CNRS 7252, University of Limoges, 16 rue Atlantis 87068 Limoges Cedex, FRANCE*

i.bachar@arcep.td, ahmed.kora@esmt.sn, roger.faye@ucad.edu.sn, christelle.aupetit-berthelemot@xlim.fr

Abstract—**This paper proposes two mathematical models as a decision tool for the choice of radio access and transmission solutions adapted to a geographical region through universal access. The first mathematical model integrates the formalism related to engineering radio network access in general as well as financial constraints imposed by the access and universal service funds. The second mathematical model is the equivalent of the first applied to radio transmission systems. Services considered are voice and data services. This approach has helped to derive two general expressions set for radio access and radio transmission technologies. The coverage and capacity deployment strategy has also been combined to clarify the optimal implementation based on financial constraints. A case study on the Ouaddai and Oura regions in Chad accompanied by simulations curves for wireless technologies as Wi-Fi, WiMAX, CDMA, and Open BTS for example has shown the efficiency of such approach.**

Keyword— **access network model, radio access, radio access model, radio transmission, radio transmission model, universal access, universal service.**

I. INTRODUCTION

Information and Communication Technologies (ICT) are crucial for the socio-economic development of peoples and contribute to the emergence of countries.

However, according to geographical membership and/or socio-economic category, the access to ICT is achieved in a non-egalitarian and disparate manner between peoples. This technological gap is explained by the fact that neither the needs for services, nor the purchasing power are the same. This leads governments to define an investment policy fostering rural areas in order to fill the gap with dense and profitable areas. In order to raise tele-density and reduce the disparities of access, the authorities and regulatory agencies have introduced the concept of universal access and services [1-4] by dedicating a fund called Universal Service Fund (FSU).

Considering the convergence and neutrality of technologies, communications infrastructures and the associated services now have a central role in economic organization [5-9]. In fact, access to these infrastructures and services depend on the ability of countries and citizens to participate in the flow of communications. For that reason, they must put in place policies which will help to avoid the exclusion of some categories of users or geographic areas deemed to be of non-profitable nature by the operators.

In this context access and universal service could be considered as a major problem. This is to ensure that quality and price for consumer satisfaction as well as profitability from the point of view of operators might be taken into account. In order to respond to this problem, the solution should come from pairing technical/economic approaches and taking into account geographical constraints inherent to each country.

Gasmi & Recuero Virto [8] have reviewed the provision policies of telecommunications services in rural areas for developing countries. They have shown that these policies differ from those usually applied in advanced countries in their basic objectives, technological strategies deployment, the role of the market and institutional environments. Falch & Henten [10] have studied the appropriate policy measures to put in place in Europe to achieve universal access. They have shown that it is interesting to implement a combination of different technologies and strategies. Xavier [11] provides an overview of the principal issues related to universal access and the provision of universal service.

Access and universal service are influenced by accessibility parameters, cost and feasibility of services. To this end, the UAS policy should consider technological innovation as a

Manuscript received on April 11, 2017. This work was supported in part by Chad the Regulatory Authority for Electronic Communications and Posts (ARCEP: Autorité de Régulation des Communications Electroniques et de la Poste) and a follow-up of the invited journal to the outstanding paper of the 18th International Conference on Advanced Communications Technology (ICACT 2016).

Dr. Idriss Saleh BACHAR (corresponding author: +235 66204775; e-mail: i.bachar@arcep.td) is with the Regulatory Authority for Electronic Communications and Posts (ARCEP Chad), BP 5808, Ndjamena, Chad. He is currently the GENERAL DIRECTOR.

Pr Ahmed Dooguy KORA (email: ahmed.kora@esmt.sn) is with Ecole Superieure Multinationale des Telecommunications, Dakar, Senegal. He is the Head of Research and Innovation Department.

Pr Roger Marcelin FAYE (email: roger.faye@ucad.edu.sn) is with the Electrical Engineering Department of Ecole Supérieure Polytechnique, Cheikh Anta Diop University, Dakar, Senegal.

Pr Christelle Aupetit-Berthelemot (email: christelle.aupetit-berthelemot@xlim.fr) is with XLIM Laboratory, SRI axis, Resyst Team, UMR CNRS 7252, University of Limoges, 16 rue Atlantis 87068 Limoges Cedex, France. She is professor at ENSIL.

suitable solution for UAS, covering rural areas and / or serving low-income populations.

In this paper, access radio and transmission technologies model for universal service are proposed. We have established a model of access network design common to radio technologies as well as transmission which have been adapted to universal service funds limitations. The number of base stations based on the project duration for each radio technology has been derived. This has made it possible to decide the optimal strategy deployment coupling the radio coverage for data and voice services. The efficiency of this approach is shown thanks to the case study applied to Ouaddai and Oura regions in Chad.

In the rest of this article Section 2 presents the modelling approach for determining the different elements of the access network and profitability model. Section 3 presents the radio modelling approach for determining the different elements of the transmission network and profitability model. Section 4 offers a case study that will highlight on the usefulness of the approach. Finally, Section 4 concludes this communication.

II. RADIO ACCESS MODELLING APPROACH

The optimal network modelling approach proposed consists in determining the optimal network architecture for the universal access and service in an area. The methodological approach to obtain this model is based on the access network model and that of the transmission network. The determination of the access network model of an area is carried out based on the telecommunications engineering parameters, notably those related to the demographic and financial aspects. Thus, through this area data, the population addressable to the universal access and the bandwidth and the necessary number of base stations are determined, then the investment and operation costs (CAPEX and OPEX) are assessed in addition the energy related expenses and liabilities are defined.

The population addressable to the universal service is given by the expression:

$$P_A = (P - P_S) \times T_N \quad (1)$$

where P is the population of the target area, P_S the population having access to the universal service and T_N the service penetration rate.

The bandwidth brought back to the addressable population is determined based on the data rate/subscriber need, the data rate by user supplied by an access technology and the contention rate. It is expressed by the following relationship:

$$BP_A = P_S \times D_A \times T \quad (2)$$

where D_A represents the data rate per subscriber, P_S the population having access to the universal service and T the contention rate.

It is worth noting that the data rate/subscriber simultaneously takes the voice and data into consideration and that the contention rate has to be taken so that, even in the most unfavorable case, the voice minimum output is kept for the user, which is translated by constraint expressing that the access technology has to easily bear the cost of the subscribers data rate needs. The determination of the necessary number of base stations of the access area allies a coverage approach with a capacity approach in order to avoid the network oversizing and under-sizing problems. Thus, this number is given by the following relationship:

$$BS_{NX} = \mathrm{m} \times BS_C + n \times BS_B \quad (3)$$

where $BS_C = \frac{S_C}{S_{BSC}}$ and $BS_B = \frac{Bp_A}{CapBS_X \times \mathcal{T}_u}$

with S_C the surface to cover and S_{BSC} the surface covered by a base station, $CapBS_X$ the bandwidth base station capacity brought back to a technology X and $\mathcal{T}_u$ this station use rate, m and n are the coefficients related to the coverage and capacity needs. From equation (3), the BS_X is expressed in function of m by the following expression:

$$BS_{Nx} = (m \times BS_C + (1 - m) \times BS_B) \quad (4)$$

The total cost of the investment expenses (CAPEX) of a technology X is given by the expression:

$$C_C = BS_N \times capex(BS_X) \quad (5)$$

where $capex(BS_X)$ is the investment unit cost of a given technology X.

As for the total cost of the operation expenses (OPEX) of a technology X, taking into consideration its reducing percentage r, it is determined by the expression:

$$C_O = BS_N \times opex(BS_{XN}) \quad (6)$$

with $opex(BS_{XN}) = opex(BS_{X(N-1)}) \times (1 - r)$, and where $opex(BS_{XN})$ is the operation unit cost of a base station at year N brought back to technology X.

As a matter of fact, the operation decreases each year with a positive constant reducing percentage r. This decrease is due to the fact that a piece of equipment is used, some mastery is acquired which reduces the operation cost as the years go.

The access total cost of a technology X is the sum of total CAPEX, OPEX total operation over the whole duration of the project and allied expenses. The allied expenses include the investment and operation expenses of the liability infrastructures as well as those of energy workshops. Taking into account, on the one hand, that the OPEX cost represents 5% of the CAPEX costs [12] and, on the other hand, that the energy OPEX cost represents 25% of the CAPEX in energy [12], the investment and operation costs of the liability infrastructures as well as those of the energy workshops, while simultaneously integrating the OPEX and CAPEX costs, are determined by the following expressions:

$$CTI_X = 1.05 \times BS_N \times c_i \quad (7)$$

$$CTE_X = (1.25 \times c_e) \times \sum_{k=0}^{T} BS_{NXk} \quad (8)$$

with c_i the liability infrastructure unit cost and c_e the energy unit cost.

Thus, the allied expenses CC are given by the expression:

$$CC = CTI_X + CTE_X \quad (9)$$

whereas the access total cost is given by the following relationship:

$$CTA_X = CC + C_C + \sum_{k=0}^{T} C_{OXk} \quad (10)$$

Expressing the OPEX summation of the access technology and using equation (5), it is possible to write:

$$\sum_{k=0}^{T} C_{OXk} = BS_0 \times opex(BS_{X0}) + BS_1 \times opex(BS_{X1}) + \cdots + BS_T \times opex(BS_{XT}) \quad (11)$$

where $opex(BS_{X1}) + \cdots + BS_T \times opex(BS_{XT})$ and $opex(BS_{X2}) = opex(BS_{X1}) * (1 - r)$

The following expression is obtained:

$$\sum_{k=0}^{T} C_{0Xk} = opex(BS_{X0}) \times [BS_0 + BS_1 \times (1-r)^1 + \cdots + BS_T \times (1-r)^T] \quad (12)$$

Thus, the total cost of the access network is determined by the following global expression:

$$CTA_X = CC + C_C + opex(BS_{X0}) \times [BS_0 + BS_1 \times (1-r)^1 + \cdots + BS_T \times (1-r)^T] \quad (13)$$

In practice, a region or an area is the object of a commercial launching when the total set of stations are deployed. This simplifies the expression (13) which becomes:

$$CTA_X = BS_X \times \{1.05 \times c_i + (1.25 \times c_e) \times (T+1) + capex(BS_X) + opex(BS_{X0}) \times [1 + (1-r)^1 + \cdots + (1-r)^T]\} \quad (14)$$

$$CTA_X = BS_X \times \{1.05 \times c_i + (1.25 \times c_e) \times (T+1) + capex(BS_X) + opex(BS_{X0}) \times [1 + (1-r)^T]/[-r]\} \quad (15)$$

For a given technology, it is possible to establish a connection between the *opex*(BS_{X0}) and the *capex*(BS_X). Suppose in this case that this connection is α, then expression (16) becomes:

$$CTA_X = BS_X \times \{1.05 \times c_i + (1.25 \times c_e) \times (T+1) + capex(BS_X)\ [-r + \alpha + \alpha \times (1-r)^T]/(-r)\} \quad (16)$$

Then, we can finally get BS_X expression as follows:

$$BS_X = \frac{CTA_X}{\left\{1.05 \times c_i + (1.25 \times c_e) \times (T+1) + \alpha - \alpha \times \frac{[1+(1-r)^T]}{[-r]}\right\}} \quad (17)$$

In a given locality, the access technology X to choose will be the one that will have the lowest access total cost CTA_X among all the technologies submitted to this algorithm.

This profitability makes it possible to evaluate the total amount of the subsidy necessary to achieve the project but also the adequate purchasing power (ARPU) needed to ensure the population accessibility to the service. The analysis of the model shows that the whole set of the expenses from which the subsidy on the project duration is subtracted has to be lower than what the operator will earn over the same duration (number of subscribers over the project study duration multiplied by the ARPU.

III. RADIO TRANSMISSION MODELLING APPROACH

The radio transmission model presents all the equations that ensure the transmission of information between covered area and the core of the network through the national backbone. As with the access model, the elaboration of the transmission model follows several steps. These steps are presented through the following lines:

Determining the number of active relay stations to reach the backbone is estimated with the following formula:

$$N_{XT} = \frac{D}{D_{XT}} \quad (18)$$

where the number of active relay stations N_{XT} is determined by the ratio of the distance between the operator network (*D*) over the range of an *XT* (D_{XT}) radio transmission technology. Let's consider that the cost of an active relay station is the same as that of the main station. The verification of the capacity provided by *XT* transmission technology consists in reassuring that the throughput offered by the transmission technology can withstand the throughput that will be submitted to it during the entire study period of the project. This is done based on the following inequality:

$$BP_{XT} > (A5voice_T * \alpha) + A5data_T \quad (19)$$

The (19) inequality above means that the capacity of the transmission technology is greater than the sum of the total off-net voice rate (A5voiceT * α) in addition to the total data rate in the previous project year of study (A5dataT) to ensure that the dimensioning is adapted throughout the duration of study T of the project. The total CAPEX cost of the XT transmission technology is given by the following formula:

$$B2_{XT} = CAPEX_{XT} * (N_{XT} + 1) \quad (20)$$

The total CAPEX cost of transmission technology ($B2_{XT}$) is calculated by multiplying the number of active relay stations plus the main station by the CAPEX of a transmission technology station. The total cost of the OPEX of the XT transmission technology is given by the following relation:

$$B3_{XT} = B3_{XT0} * [\frac{1-(1-r)^{T+1}}{r}] \quad (21)$$

As for access technology, the OPEX transmission technology is clean every year. Indeed, the latter is subject to a decrease over the years due to the reduction coefficient ''r'' of the OPEX in transmission. One gets:

$$B3_{XTN} = OPEX_{XTN} * (N_{XT} + 1) \quad (22)$$

which represents the cost of the OPEX of a transmission technology *XT* to year *N*; the number of transmission stations is multiplied by the cost of OPEXs in year *N*. However, OPEXs are reduced each year due to the progressive control of the technology. The cost of the OPEX $B3_{XTN}$ is therefore a geometric sequence based on (1-*r*) with $r \neq 1$ and $r \neq 0$. Thus, one can easily determine the sum of the OPEX of the radio transmission technology *XT* over the duration of the project as follows:

$$\sum_{k=0}^{T} B3_{XTk} = B3_{XT0} * [\frac{1-(1-r)^{T+1}}{r}] \quad (23)$$

This justifies the expression of the total cost of the OPEX $B3_{XT}$ over the study duration *T* of the project.

In order for the operator to have access to the Internet, he must pay an annual cost according to the total data throughput of a specific year. To actually calculate this cost over the duration of study *T* of the project, the following expression (24) can be used:

$$B3data = B6data * \sum_{k=0}^{T-1} A5data_k \quad (24)$$

where the total cost of Internet access (*B3data*) is calculated by multiplying the total data rate over the entire duration of the project ($\sum_{k=0}^{T-1} A5data_k$) by the cost per Mbps which is set by the legislation of a given country (B6data).

To allow network users to communicate with subscribers of another operator, the operator must pay a cost of voice-over-net traffic. The total cost of voice over-net traffic can be written as :

$$B3voice = (\sum_{k=0}^{T-1} A5voice_k) * \alpha * B6voice \quad (25)$$

The total cost of off-net voice traffic is determined by first calculating off-net voice traffic which is a portion of overall voice traffic. Then one multiplies the overall voice traffic over the entire duration of the project ($\sum_{k=0}^{T-1} A5voice_k$) by the percentage of voice-over-net traffic (α). The off-net voice traffic thus obtained is multiplied by the cost per Mbps (B6voice) which is set by the legislation of a given country.

The total associated transmission cost representing the passive infrastructure costs (Mat, Shelter, Pylon) as in the access model, is given by:

$$CTI_{PXT} = (N_{XT} + 1) * CUI_P * [1 + 0.05T] \quad (26)$$

The method applied to determine this associated costs in transmission is similar to that described in access. Actually, the total cost in passive infrastructure of transmission technology (CTI_{PXT}) is calculated by multiplying the number of transmission stations ($N_{XT} + 1$) by the infrastructure cost of a transmission station (CUI_P) and by [1 + 0.05 * T] to be able to directly cover the cost of OPEX and CAPEX in passive infrastructure simultaneously as OPEX in infrastructure represents 5% of CAPEX in passive infrastructure (CUI_P) and the number of transmission equipment remains the same over time T study project.

IV. CASE STUDY

In order to apply and assess the proposed approach, as an illustration, the Ouaddaï (Chad) region is considered. It has an area of 36,685 km^2 including a population of 1 367 166 inhabitants. This area includes three localities with identical needs in data rate/inhabitant but the needs in bandwidth differ from a locality to another. Tables 1 and 2 below sum up the set of collected data.

Table 1 represents the actual data of the Ouaddaï region (Chad) with locality1 situated in city centre, locality 2 situated in periphery and locality3 situated in rural zone. This distribution corresponds to the administrative division: the zone corresponds to the region; the locality corresponds to the three departments which are distributed into communities.

TABLE I
OUADDAÏ AREA BASIC DATA (SOURCE ARCEP CHAD)

Data	Locality 1	Locality 2	Locality 3
Area (km^2)	11 611	15 229	9 845
Population	852 389	388 448	126 329
Penetration rate	43.66	43.85	44.40
Need in output/subscriber (Kbps)	256	256	256
Population Ps	371 547	170 755	56 078
Addressed Population (PA)	209 647	95 350	31 121
Appropriate bandwidth (Bp_A) by Mbt/s	53 669 660.67	24 409 480.70	79 67 025.41

This table makes out for each considered locality:

- the population data (geographical area, number of inhabitants);
- the subscribers park of the set of electronic communications services;
- ICT penetration rate;
- needs in output/subscriber and necessary bandwidth (BP_A).

The analysis of table 1 reveals that according to IUT's definition of universal access, it is important to have an output of 256Kbps to supply the necessary services. For the set of considered localities, a penetration rate inferior to 45% is recorded. The penetration of services related to the data is low, which justifies the significant need in bandwidth of the localities.

Table 2 below gives the outputs supplied by the different technologies, the surfaces covered by a base station (BS) of technology X as well as the maximum capacity of BS's. It also shows the CAPEX, OPEX of the base stations by technology and the cost of liability infrastructures as well as those energy-related.

TABLE II
DATA RELATED TO TECHNOLOGIES

Data	WIFI	WIMAX	CDMA
Data rate (D_X)	54	70	3.1
Surface covered by BS (S_{BSC})	0.13	200.96	5024
BS capacity ($CapBS_X$)	100	30	64
CAPEX (BS_X) in Euro	13.71	1 494	68 597.561
$OPEX$ (BS_X) in Euro	2.06	224.08	10 289.63
CTA (Euro)	1 524 390.24	1 524 390.24	1 524 390.24
C_i	1	2 003	10 015
C_e	7 621.95	25 914,63	85 129.57

After analysing tables 1 and 2, the number of base stations by technology is determined following equation (17) and according to the following conditions:

- variation of duration T of the project as well as that of the OPEX coefficient reduction r;
- only at the variation of the reducing coefficient r;
- variation of coefficient m linked to the coverage in accordance with equation (4).

Figure 1 below represents the number of stations by technology according to the variation of the reducing coefficient and the project duration. This graph makes it possible to see the evolution of the BS_X of the zone, for the same r and T the number of BS_X differs according to technology X. It is worth noting that if the project duration T increases, the number of BS_X decreases.

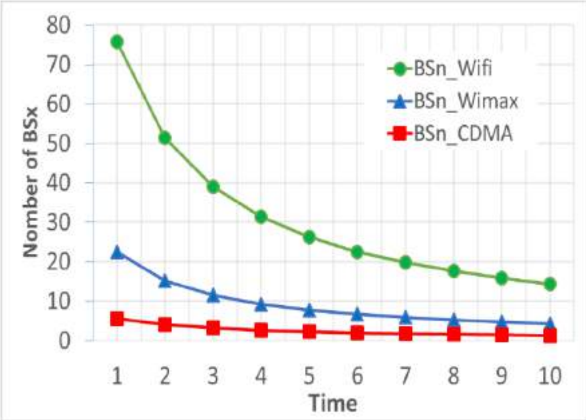


Fig. 1. Evolution of the number of base stations by technology according to a variation of duration T and reducing coefficient.

Figure 2 shows the evolution of the base stations of three access technologies (Wi-Fi, WiMAX and CDMA in accordance with the variation of reducing coefficient r. Based on the depreciation of the telecommunications equipment, the project duration T is 5 years. It established that if the duration T is constant, the variation of the reducing coefficient r has no effect on the number of BS_X. The BS_X by technology practically remains constant even if r varies.

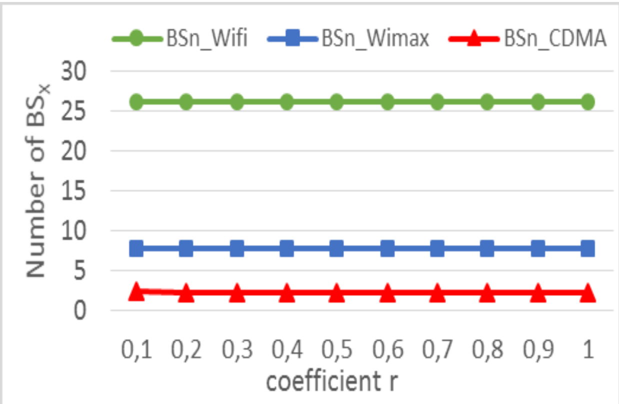


Fig. 2. Evolution of the number of base stations by technology in accordance with coefficient r.

Figure 3 shows the evolution of the number of base stations of three technologies following the deployment approach directed to coverage and capacity coverage objectives. When m varies, it is noted that for a technology X, the needed number of stations varies significantly. It is worth indicating that for the two extreme values (0 and 1) of m, the base station number decreases very significantly following technology X. This shows that it is easier to reach the coverage goals than those related to the quality of service and capacity. Thus, it is noted that the CDMA technology allows the coverage objectives to be reached more easily, the Wi-Fi and WiMAX, on the other hand, are more efficient for capacity oriented deployment.

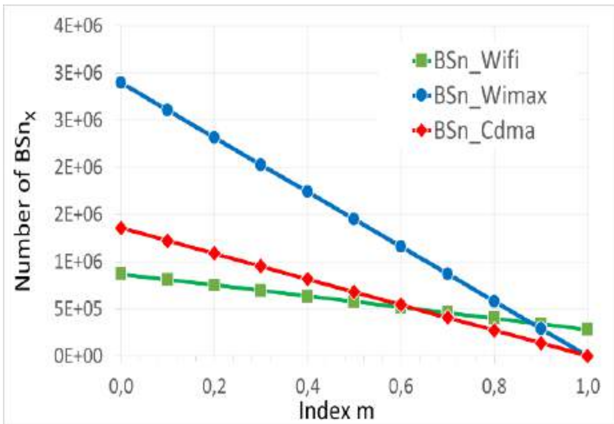


Fig. 3. Evolution of the number of base stations by technology according the m variation.

TABLE III

OURA AREA BASIC DATA (SOURCE ARCEP CHAD)

Data	Access	Data	Transmission
Area (Km²)	15 229,0	Space segment rental cost for 1 Mbps	7000 euros/month
Rate of growth	3,1	Local backbone rental cost	147000/Mbps
Need in output/subscriber (Kbps)	256	Percentage of off-net voice traffic (%)	5,6
Need for speech rate (in kbps)	9,1		
Population with access to the service (voice and data)	170 756	Distance between access zone and backbone (km)	142
Growth rate subscribers to the service	12,1		
Contention rate	1:97	-	-

To illustrate the combined case of access and transmission, we present in the last part of this section the results of a real case of universal access project. The target area is OURA, a rural region of Chad which information for the deployment of technologies for universal access is presented in Table 3.

The project is studied over a 5-year T-term. Given that it is a rural area, the option considered includes a solar power equipment as cost effective solution. Passive infrastructures as Shelter and pylons allow the technologies to reach their maximum range.

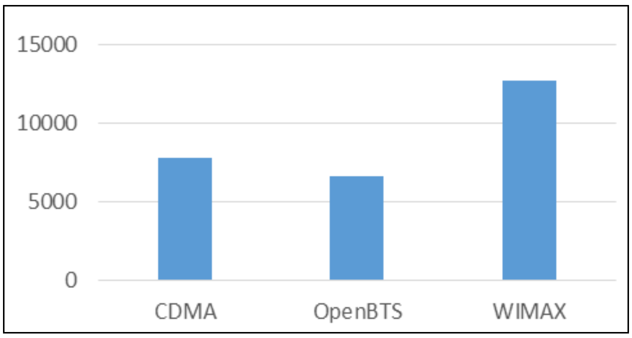


Fig. 4. Universal service fund grant cost comparison in CFA for a different access technologies using microwave for transmission.

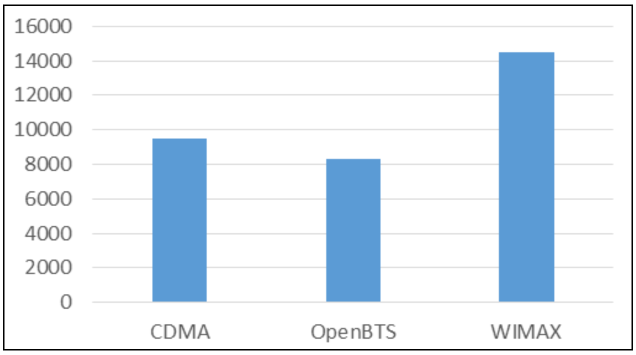


Fig. 5. Universal service fund grant cost in CFA comparison for a different access technologies using Wimax for transmission.

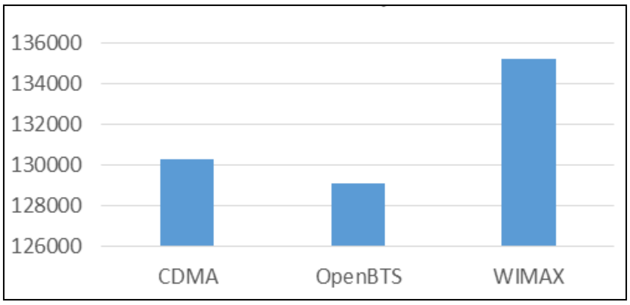


Fig. 6. Universal service fund grant cost in CFA comparison for a different access technologies using VSAT system for transmission.

As the penetration rate of service is about 44% with these figures, we have planned for this test a projected service penetration rate of 50%. Several combinations of access and transmission technologies have been investigated as shown in Fig.5, 6 and 7. The amount of 655.55 FCFA correspond to one Euro.

The analysis of these figures shows that the Open BTS-microwave combination is the most suitable at Oura region for this universal access project. The amount of the subsidy is 10 053 424 Euros. The people of this zone will have to pay to the operator about 9.12 Euros per year or at least 0.76 Euro per month to obtain the services. The operator will make a turnover of 1057810 Euros out of the five (5) years of study of the project.

It should be noted that for the purposes of these tests, it is assumed that the WIMAX and VSAT technologies can transmit the calculated bandwidths. To enable such transmission capacity, new transmission techniques such as MIMO for WIMAX and large VSAT stations should be used, given the density of the population, which will lead to even higher costs. For VSATs, the case is even more critical because the rental cost of the space segment is immeasurable. This confirms that VSATs cannot be used for areas with a relatively high population for universal access projects at affordable cost.

V. CONCLUSION

The aim of this paper was to suggest an optimal model to define the network architecture based on radio technologies for universal access and services. This approach makes it possible on the basis of the universal service access fund allocated to each locality to determine the communication needs in terms of output, bandwidth and the amount of equipment needed by technology. To ensure ideal overall accessibility in an area *i*, the technical solution envisaged must integrate the specific economic and geographical constraints of that locality. Also, the simulations showed that several possibilities could be envisaged to remedy the constraints linked to the development of universal access. However, the choice of the appropriate solution depends on the cost C of the technologies to be deployed in an area *i* calculated on the basis of its inputs

The results of the simulations of the UAI, orient us towards combined solutions (access and transmission) thanks to the application to the Ouaddaï and Oura areas located in Chad which allow the gradual deployment policy, distributed over a duration, of the cheapest cost coefficient network.

REFERENCES

[1] Idriss Saleh Bachar; Ahmed Dooguy Kora; Roger Marcelin Faye; Christelle Aupetit-Berthelemot ''Assessing the Radio Access Technologies Impact on the Universal Access Index'', *IEEE Access*, Vol. 5, 2017, p. 911-917. DOI: 10.1109/ACCESS.2016.2615467.

[2] Zacharia Damoue; Ahmed Dooguy Kora; Ramlatou Diallo; Cheikh Brahim Rabany; Samuel Ouya, ''Strategies and types of national design of a ROADM transmission network for universal access'' *11th International Conference on Computer Engineering & Systems* (ICCES), 2016, p. 360-365. DOI: 10.1109/ICCES.2016.7822030.

[3] R. N. Muniz; J. A. S. de Sá; B. R. P. da Rocha, ''Challenges and opportunities for universal access to electricity in the Amazon'' *5th International Youth Conference on Energy* (IYCE), 2015, p. 1-6, DOI: 10.1109/IYCE.2015.7180796.

[4] Yu Hsuan Chen; Sherman Lo; Per Enge; Shau Shiun Jan ''Evaluation & comparison of ranging using Universal Access Transceiver (UAT) and 1090 MHz Mode S Extended Squitter (Mode S ES)'' *IEEE/ION Position, Location and Navigation Symposium* - PLANS 2014, p. 915 - 925, DOI: 10.1109/PLANS.2014.6851456

[5] Mehwish Bashir & Salman Afsar, "Implementation of Universal Mobile Telecommunication System", *J. Agri. Soc. Sci.* Vol. 2 N°1, p. 33-37, 2006.

[6] Mugen Peng; Chonggang Wang; Vincent Lau; H. Vincent Poor, "Fronthaul-constrained cloud radio access networks: insights and challenges. Wireless Communications", *IEEE*, Vol. 22, Issue 2, p. 152-160. DOI: 10.1109/MWC.2015.7096298, 2015.

[7] Issac Albarran & Manuel Parras, "Telecommunication Services Migration to the Cloud, a Network Performance", *Master Thesis, School of Information and Communication Technonology*, KTH Royal Institute of Technology, 231 pages, 2012.

[8] Dietrich Hunold; André Noll Barreto; Gerhard P. Fettweis; Michael Mecking, "Concept for Universal Access and Connectivity in Mobile Radio Networks", *11th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, (PIMRC 2000), London 18-21 Sep., Vol.2, p. 847 – 851, doi: 10.1109/PIMRC.2000.881542, 2000.

[9] Farid Gasmi & Laura Recuero Virto, "Telecommunications Technologies Deployment in Developing Countries: Role of Markets and Institutions", *Communications & Strategies*, N°58, p. 19-45, 2005.

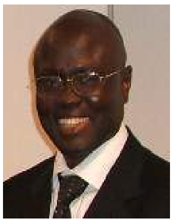
[10] Morten Falch and Anders Henten, "Achieving Universal Access to Broadband", *Informatica Economica*, 2009, vol. 13, issue 2, pages 166-174.

[11] P. Xavier," Universal Access for telecommunications in a competitive environment", *OECD – World Bank Fifth Services Experts Meeting*, 3-4 February, 32 pages, Paris, 2005.

[12] IFC/World Bank, "Technical Aspects and Regulation", *AZTELCO*, pp. 189, November 2012.

Bachar Saleh Idriss was born in CHAD on 27/09/1984. He got the Ph.D. degree in telecommunication from the University of Limoges, France, in 2016. He is the GENERAL DIRECTOR of National School of Information and Communication Technology from June 05 up to now. From August 31, 2010 to June 05 GENERAL DIRECTOR of the Regulatory Authority for Electronic Communications and Posts (ARCEP CHAD). From 2010 to May 31, 2011, he was president of the Association of Telecommunications Regulators of Central Africa (ARTAC) and Vice President of the Commission recast texts Officer (Electronic communications, telecommunications regulation and Postal, cybersecurity, Cyber criminality). His research activities cover low cost access network and universal services solution appropriate to Africa.
Dr. BACHAR is member of the "Association pour le Developpement de l'Informatique Libre (ADIL) " and the REPTIL in CHAD.

Ahmed D. KORA was born in Parakou (Benin Republic) on May 17, 1971 He is graduated in Physics Sciences in 1998 from "Faculté des Sciences Techniques" at "Université d'Abomey–Calavi", Bénin, where he got his Diplôme d'Etude Approfondie (DEA) in Material Sciences in 2000. In 2003, he received a Master "Réseaux Télécoms" degree from "Ecole Superieure Multinationale de Telecommunications" (ESMT) and the Ph.D. degree in telecommunication from the University of Limoges, France, in 2007.
He is currently with the ESMT and Head of Research and Innovation Department. His research area covers communications, radio and optical networks system architecture, universal access, mobile network quality of service and quality of experience, low cost IT systems for development, etc. Prof. KORA is IEEE member and also member of Fiber Optic Association.



Roger Marcelin FAYE was born in Thiès (Senegal) on 09/12/1961. He received the engineer degree in Electrical Engineering from ENSUT (Ecole Nationale Supérieure Universitaire de Technologie) Dakar-Senegal in 1989. He obtained the MSc in Control and Modelling Industrial Processes from Paris 12 Val de Marne University, Paris-France in 1994 and his PhD in Automatic Control and Operational Research from University of Toulouse III Paul Sabatier, Toulouse-France in 1999.
He is currently full Professor at Ecole Supérieure Polytechnique (ESP) and was the head of Electrical Engineering department at ESP from 2010 to 2012. He is author and/or co-author of several publications and two books in the fields of Automatic Control. His research activities cover but not limited to modelling systems and to IT solutions for Africa.
Prof. FAYE is member of the Senegalese society of complex systems.

Christelle Aupetit-Berthelemot was born in Limoges (France) in 1971. She received the engineer degree in telecommunication from ENSIL (Ecole Nationale Supérieure d'Ingénieurs de Limoges ENSIL-France) in 1995. The same year, she received the M.S. degree and in 1998, a PhD degree in High Frequency and Optic Telecommunications from University of Limoges. She is currently full Professor and the head of Electronic and Telecommunications department at ENSIL. Her current research activities concern optical telecommunications and microwave photonics. Particularly, her interests are focused on the study of the impact of the components on the system performances, integration of digital techniques of signal processing in optical communication, Radio Over Fiber, and optoelectronic devices characterization. She has been involved in several Cooperative Projects. She is author and/or co-author of more than 100 publications. Prof. AUPETIT-BERTHELEMOT is editor in Chief of J3EA review and member of Optical French Society (SFO), of french club EEA and GDR SoC²

Volume 6 Issue 3, May. 2017, ISSN: 2288-0003

ICACT-TACT JOURNAL

Global IT Research Institute

1713 Obelisk, 216 Seohyunno, Bundang-gu, Sungnam Kyunggi-do, Republic of Korea 13591
Business Licence Number : 220-82-07506, Contact: secretariat@icact.org Tel: +82-70-4146-4991