An Improved Overlay-based Data Processing Architecture Tolerant to Physical Network Disruptions using load balanced Servers

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***Abstract*— Organization arrangement for especially versatile data taking care of has not been all that much focused on paying little heed to the way that massive data planning gives various critical and basic information for us. An overlay-based parallel data imparting and transmission auxiliary arranging, which executes totally scattered data organization and planning by using the overlay framework, can centre to exceedingly evolving circumstance. The overlay-based parallel structural engineering arranging is not fit for giving data transmission advantages in the occasion of the physical framework aggravation that is made by switch/correspondence line breakdowns because different centre points are ousted from the overlay framework. To conquer this issue, this paper proposes an overlay framework advancement arrange in perspective of system territory in physical framework, and an appropriated task bit arrangement using overlay framework development. A heap adjusting plan among the servers is joins close by the overlay framework. The test demonstrates that the overlay organize in the proposed plan amazingly moving faster the routine arrangements in regards to organization availability against physical framework intrusion.**

Keywords*— Query; Result Verification; Tiered Sensor Networks; VQ Systems

I. INTRODUCTION

With the quick improvement of the data and correspondence advances, "huge information" has been created from different perspectives, for example, online exchanges, logs, seek inquiries, wellbeing records, long range informal communication data, science information, et cetera. It is generally perceived that enormous information mining is a key segment that is needed for the realization of savvy society [1]. Since enormous information contains different sorts of information, (for example, email, social networking, feature, and sensor information), the huge information mining gets to be exceedingly unpredictable. Furthermore, the huge information mining needs to yield result information speedily in reaction to the ongoing interest [2]. Consequently, ordinary information mining utilizes parallel information mining architectures, for example, MapReduce [3] and Hadoop [4] to satisfy these necessities.

In those architectures, the information handling is executed by particular hubs (called transforming hubs) however framework administration undertaking is served by an expert hub. While such an incorporated administration plan improves the outline and execution, this plan needs adaptability in light of the fact that the unified administration regulated by an expert hub may diminish the framework execution when the quantity of hubs increments [5]. Moreover, since the expert hub is a solitary purpose of disappointment, the administration accessibility can significantly diminish when the expert hub stops to capacity. From these reasons, versatility and administration accessibility are discriminating issues for parallel information mining building design.

As a solution for enhancing adaptability, an overlay-based parallel information mining structural planning has been proposed. Since all the hubs execute both administration and transforming capacities by utilizing overlay organize, this structural planning can adjust the administration load. Moreover, this building design attains to higher administration accessibility against the breakdown of expert hub in light of the fact that it continues giving the information mining until overlay system is disturbed.

Then again, this structural planning can't guarantee the administration accessibility against physical system interruption (e.g., switch breakdown because of equipment inconvenience or DDoS assaults) [6]. The physical system disturbance does not just prompt the stop of capacity of the harmed switch additionally upsets the interchanges of the servers, which are associated with the harmed switch. As it were, various hubs are expelled from the overlay arrange by the physical system disturbance. This outcomes in a rise of detached hubs in the overlay system and declines the administration accessibility of the information mining.

To manage the aforementioned issue, we propose an overlay-based parallel information mining structural planning that is tolerant to physical system interruption. Our proposed structural planning is outlined taking into account the joining of overlay and physical systems. This paper proposes an overlay system topology for amplifying the network against server breakdowns.

Moreover, overlay system development and undertaking assignment plans are proposed for augmenting the administration accessibility against physical system disturbance.

II. PARALLEL DATA MINING ARCHITECTURE

In this segment, we present the traditional parallel information mining structural engineering in view of the incorporated administration instrument. At that point we portray the current works that mean to enhance the administration accessibility, trailed by the weaknesses of these current plans. Besides, we depict an overlaybased parallel information mining structural engineering that can defeat the shortcoming of the ordinary building design.

A. Routine parallel information mining building design
MapReduce is the most prevalent structural planning for parallel huge information mining [4], [7]. In MapReduce, servers are arranged into two sorts of hubs, i.e., a solitary expert hub and numerous preparing hubs. While the expert hub calendars mapping and lessening procedures and oversees document name space operations (i.e., open, close, and rename), the preparing hubs store information and execute mapping and decrease forms.

At the point when an information preparing appeal is infused, the expert hub parcels the assignment into some information squares, which are conveyed to particular handling hubs. At that point, every preparing hub (called mapper) performs the mapping methodology, which characterizes a lot of data and selects the data needed for the following procedure. After the mapping process, the expert hub chooses a reducer, which performs the lessening methodology, from mappers. The reducer incorporates the data removed in the mapping process and yields the investigated results.

Since mapping and lessening methodologies are executed in circulated way, MapRecue can execute the information mining at the rate relative to the quantity of servers. Furthermore, important existing works led in [8]–[12] grew superior parallel information mining architectures regarding preparing velocity, system asset proficiency, computational asset effectiveness, and vitality productivity. Notwithstanding the noteworthy preferences, those architectures still experience the ill effects of server breakdowns in light of the fact that the achievement likelihood of information mining reductions when the servers fizzle because of equipment inconveniences or programming bugs [13], [14].

To adapt to this issue, the regular MapReduce structural engineering (e.g., current Hadoop [15]) repeats every information square and disperses the recreated ones to particular hubs, which builds the administration accessibility against server breakdowns.

Moreover, current Hadoop uses numerous expert hubs component to expand administration accessibility against the breakdown of expert hub. Notwithstanding, it is hard to guarantee the administration accessibility under genuine environment since the ideal quantities of replications and expert hubs rely on upon the likelihood and size of breakdowns.

The works [16], [17] proposed preparing planning method that can abbreviate execution time of the information mining under disappointment inclined environment. In any case, on the grounds that these works expect the size of server breakdowns is little, the capacity of information mining is significantly diminished when a bigger size of breakdown, for example, physical system interruption, happens. In this manner, a parallel information mining building design that is tolerant to physical system disturbance is completely basic to give future "pervasive enormous information mining administration

B. *Overlay-based parallel data mining architecture*
Overlay-based parallel information mining is one of architectures that enhance the administration accessibility against server breakdowns [18]–[20]. In this structural planning, all the servers execute both administration and handling capacities. The overlay system is developed by all servers and used to discover preparing hubs, like the expert hubs in the traditional structural planning. This structural planning can continue giving the administration regardless of the fact that a few hubs are expelled from the overlay system.

Fig. 1 demonstrates a sample of mapping and decrease forms in the overlay-based parallel information mining construction modeling. At the point when an information handling appeal is infused, a hub that got the solicitation (hub An in the Fig. 1) executes a gathering capacity by utilizing the overlay system. As such, the hub discovers mappers by utilizing flooding message, where mappers are haphazardly chosen (hubs B, C, and D in the Fig. 1). At that point, a mapper that at first completed the mapping procedure (hub D in the Fig. 1) turns into a reducer, and it demands to different mappers to transmit the transformed information to itself, where the solicitation message can be sent by utilizing flooding plan.

In the wake of accepting the prepared information from mappers, the reducer executes the decrease process and yields the investigated result.
In this structural engineering, subsequent to the integration of overlay system drastically influences the administration accessibility of information mining, there are various works, which handled the network issue from the different perspectives, i.e., connection mindful, diagram hypothesis based, and complex system hypothesis based overlay system development plans [21]–[24]. These works make overlay arranges that are tolerant to little scale server breakdowns yet don't consider the huge scale server breakdowns, i.e., physical system interruption. In this manner, this paper builds up an overlay-based parallel information mining structural engineering that is tolerant to physical system interruption so information mining is accessible at whenever,

anypl

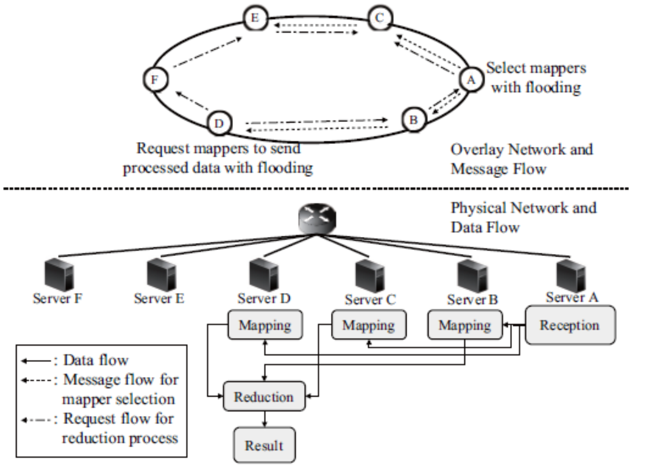


Fig. 1. Mapping and reduction processes in overlay-based parallel data mining architecture.

III. OVERLAY-BASED PARALLEL DATA MINING ARCHITECTURE

In this segment, we propose a novel overlay-based parallel information mining structural engineering to enhance the administration accessibility against server breakdowns and physical system interruption by using physical system data. To start with, we present an overlay system topology taking after a bimodal degree circulation for boosting integration against server breakdowns.

At that point, we propose a neighbor determination plot so as to enhance the quantity of accessible hubs after physical system disturbance happens. Besides, an assignment allotment plan, which succeeds in information mining under physical system interruption is proposed.

A. Overlay system topology in view of bimodal degree dispersion

We present an ideal overlay system topology that is tolerant to server breakdowns brought on by equipment inconveniences and DDoS assaults. While equipment inconveniences cause irregular expulsion of hubs from the overlay arrange paying little mind to the level of hubs, DDoS assaults uproot higher degree hubs since malignant aggressors endeavor to disturb the overlay system. To accomplish high network against both equipment inconveniences and DDoS assaults, this paper concentrates on overlay Based on the ideal bimodal degree dispersion, an ideal system topology for boosting integration against server breakdowns has been produced [24]. Fig. 2 demonstrates an ideal system topology when k is about equivalent to 3. The LNs are characterized into Normal Leaf Nodes (NLNs), which interface with a SN, and Extra Leaf Nodes (ELNs), which don't unite with a SN yet associate with different ELNs. This topology is isolated into various littler gatherings. Every gathering system taking after a bimodal degree dissemination.

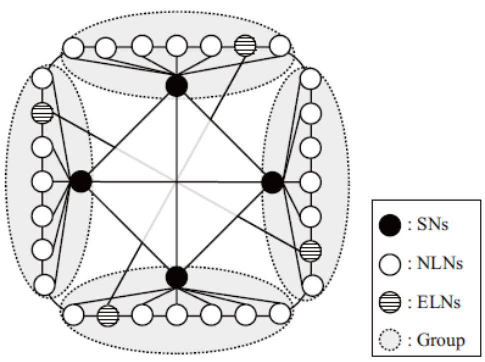


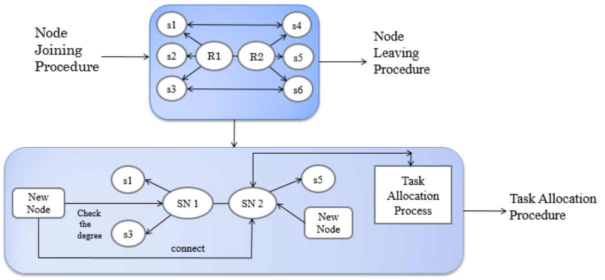
Fig. 2. An optimal network topology which is tolerant to server breakdowns.

B. *Physical system mindful neighbor choice*

Since the neighbor choice plan influences the network of overlay system, we propose a neighbor determination plan to develop an overlay organize that attains to higher integration against physical system interruption. The physical system disturbance has a particular trademark, for example, "area", i.e., servers associating with the breaking down switch are expelled from the overlay system. Accordingly, it is attractive that the servers that are associating with the same switch (or situated in the same region) in the physical system get to be neighboring hubs (or have a place with same gathering) in the overlay system, as indicated in Fig. 3. In this neighbor choice guideline, a large portion of the connections of the uprooted hubs are additionally the connections to other evacuated hubs. As such, this plan can accomplish higher network against the physical system disturbance in light of the fact that there remain a great deal of connections between the surviving hubs.

Keeping in mind the end goal to build an overlay system taking into account our neighbor choice guideline and ideal system topology, we propose two methodology: (i) hub joining strategy and (ii) system support method. The hub joining technique is self-governingly executed by a recently joined hub (NJN) to convey the administration burden to all hubs. In the hub joining technique, a NJN chooses the servers that are situated in the same region in the physical system as neighboring hubs in the overlay system. Then again, SNs intermittently execute the system support strategy, which reproduces system to keep the ideal system topology.

Bunch development process – The target of this procedure is to build new gatherings with the increment in the quantity of hubs. In the first place, the NJN chooses a hub from the greatest gathering as another SN. The ideal degree of the newly created SN is calculated according to (1). Then, the ESN constructs a new group by dividing the AG of the newly created SN into two smaller groups evenly.



Procedure 1 Node joining procedure

Get inter-group list L_{inter}
Select group g as Affiliation Group (AG)
Join group g
Get intra-group list L^{g}_{intra} which is shared in group g
Establish connection with nodes of group g
Get intra-group list $L^{g'}_{\text{intra}}$ which is shared in group g' which is at diagonally-cornered of group g
Establish connection with LNs of group g'
Update L^{g}_{intra} and $L^{g'}_{\text{intra}}$

Procedure 2 Network maintenance procedure

Update the inter-group list L_{inter}
if $N_s < N'_s$ **then**
  Group construction process
end if
if $\epsilon < \delta$ **then**
  Regrouping process
end if

Regrouping process – In this process, the ESN restructures the groups so that the size of each group is the same as others. First, the ESN calculates the average group size, Gave. The ESN changes the AG of some nodes so that the size of smaller groups approximates Gave, where the nodes that change the AG are selected in order of nodes that are near the smaller groups on overlay network. If the selected nodes connect to the SN of the prior AG, the ESN breaks the existing link to the SN of prior AG and creates new link between the selected node and the SN of new AG.

C. Physical network aware task allocation

While the proposed neighbor selection scheme achieves higher connectivity of the overlay network and increases the available number of nodes against physical network disruption, the overlay-based data mining architecture fails to output processing result when all mappers that have same data block are removed.

IV. SERVICE AVAILABILITY ANALYSIS

In this section, we mathematically analyze the service availability of overlay-based parallel data mining architecture after physical network disruption.

A. *Node removal probability*

The physical system interruption causes various hubs to be expelled from the overlay system and the likelihood that a hub is evacuated varies relying upon neighbor determination plans. Along these lines, we demonstrate the hub evacuation likelihood in overlay organizes that is built in light of the current and proposed neighbor choice plans, separately. Here, we characterize the hub evacuation likelihood, fk, which signifies the likelihood that a hub with degree k will be expelled from the overlay system.

$$f_k^{\text{rand}} = \frac{N^R}{N}.$$

B. *Giant cluster ratio*

Since the hub evacuation influences the degree appropriation of overlay system, we infer the degree dispersion after physical system disturbance, p k, by utilizing the hub evacuation probabilities, which are demonstrated in past subsection. A group that has most extreme number of hubs after physical system interruption is alluded to as the "goliath bunch". The goliath bunch proportion, Gc, is characterized with the quantity of hubs in a titan group, Ngc, and the aggregate number of hubs in the first overlay system, N, as takes after.

$$G_c = \frac{N_{gc}}{N}.$$

C. *Success probability of data mining*

In the parallel transforming construction modeling, every errand is parceled into some information squares, which are duplicated and dispersed to particular mappers, and a reducer effectively executes lessening procedure on the off chance that it gets no less than one replication of every information hinder from the mappers. Accordingly, the likelihood that an information mining undertaking is effectively handled, Psuccess, is diminished by the hub evacuation because of physical system interruption. Psuccess is communicated with the quantity of apportioned information pieces, B, the quantity of copies, D, and the likelihood that there exists a hub that has replication i of divided information square j in giant cluster.

V. ASSESSMENT OF PHYSICAL NETWORK DISRUPTION EFFECT ON SERVICE AVAILABILITY

In this area, we expect to examine the impact of physical system disturbance on the administration accessibility of information mining. Moreover, we affirm the adequacy of our proposed construction modeling in correlation with existing structural planning that are composed without considering physical system, i.e., neighboring hubs are haphazardly chosen and information squares are conveyed in an irregular way. In this assessment, we demonstrate the quantity of accessible hubs and number of assignments that are effectively prepared to confirm the adequacy of the proposed neighbor determination and errand allotment plans, separately. Scientific outflows in past area are utilized for our execution assessment.

We assume that the physical system takes after force law degree dissemination, which is an extraordinary reality, and its topology is a tree structure, where the quantity of hubs including servers and switches is situated to 104. The overlay system is built by all hubs and takes after the bimodal degree dissemination, where the level of leaf hubs is situated to 3. We assume that a preparing errand is divided into 5 information squares and the aggregate number of transforming assignments is 103. We assess the execution of information transforming after distinctive sorts of physical system interruptions happen.

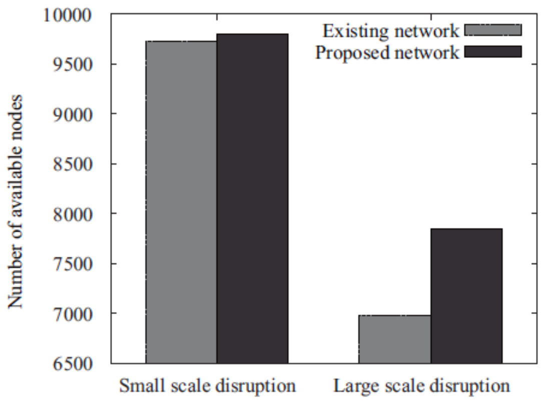


Fig. 5. The number of available nodes in different physical network disruption scenarios.

A. *Performance comparison of neighbor selection schemes*

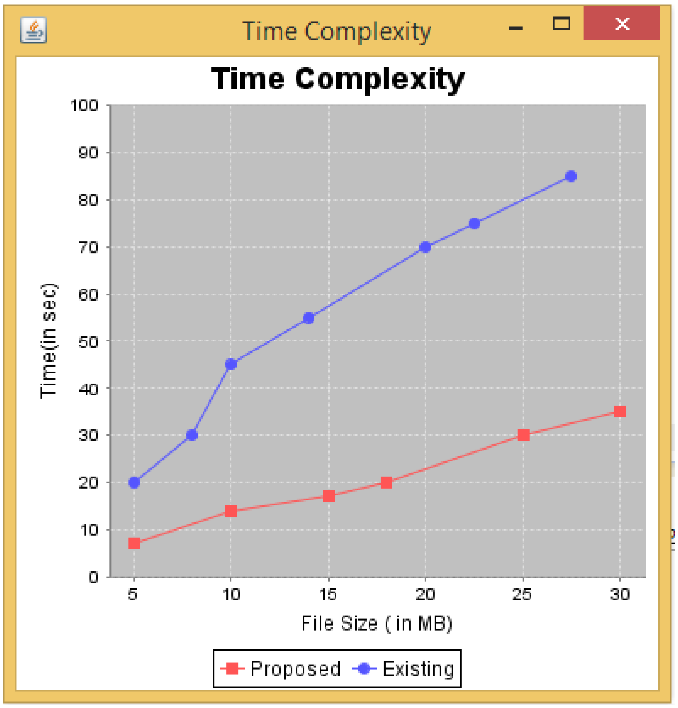
Keeping in mind the end goal to check the adequacy of the proposed neighbor determination plan, we assess the quantity of accessible hubs after a physical system interruption happens in two overlay systems, i.e., (i) overlay organize that is developed taking into account the proposed neighbor choice plan (instantly alluded to as the "proposed system"), and (ii) overlay arrange that is built in light of the arbitrary neighbor choice plan (in no time alluded to as the "current system"). We assume two sorts of physical system interruption, i.e., little scale disturbance (where roughly 2% of hubs are expelled from overlay system) and huge scale disturbance (where more or less 20% of hubs are expelled from overlay system). Fig. 5 delineates the quantity of accessible hubs in distinctive physical system interruption situations. While the quantity of accessible hubs in the current system speaks to the lower esteem, the proposed system accomplishes most extreme number of accessible hubs paying little mind to the physical system interruption situations. This is on account of the proposed overlay system is not disturbed subsequent to the evacuated hubs are situated in the same range. Besides, the proposed system accomplishes vastly improved execution when the quantity of evacuated hubs increments. Consequently, we can affirm the adequacy of the proposed neighbor choice plan.

B. *Performance comparison of task allocation schemes*

In the rest of this segment, we check the adequacy of the proposed errand designation plot by correlation of existing plan as far as the quantity of fruitful assignment after physical system disturbance. While the proposed assignment allotment repeats 2 times, the quantity of copies is situated to either 2, 3, or 4 in existing undertaking portion. In the both cases, the overlay system is built taking into account the proposed neighbor choice plan.

Fig. 6 exhibits the quantity of fruitful errands when the quantity of uprooted hubs by physical system disturbance is shifted from 0 to 4000. The current errand portion plan tumbles to an amazingly low accessibility with a dynamic increment of number of uprooted hubs regardless of the possibility that the quantity of copies increments. Then again, the proposed assignment distribution plan makes 100% progress likelihood of information mining with least replications paying little mind to the quantity of evacuated hubs on the grounds that it guarantees presence of the hubs that have an information obstruct for transforming in titan bunch. It can be inferred that the overlay-based information mining construction modeling with

the proposed neighbor choice and undertaking distribution plans can execute huge information mining with higher achievement rate and lower preparing expense.



VI. CONCLUSION

An overlay-based information mining structural engineering, which completely disperses administration and preparing capacities by utilizing overlay system advances, can possibly give adaptable information mining in huge scale system. In any case, because of physical system interruption, this building design significantly declines administration accessibility of information mining. To tackle this issue, we proposed neighbor determination and errand designation plans in light of mix of the overlay and physical systems. Keeping in mind the end goal to enhance the achievement likelihood of information mining against physical system interruption, our neighbor choice plan develops overlay system taking into account hub area in physical system and our undertaking distribution plan chooses hubs from distinctive corner to corner cornered gatherings in the overlay organize as mappers. In addition, the outcomes got from the numerical examination showed the adequacy of our proposed plans regarding critical change in the administration accessibility. Accordingly, our proposed plans can be considered to make huge information mining accessible under the system environment where physical system interruption happens.

REFERENCES

[1] N. Elmqvist and P. Irani, "Ubiquitous analytics: Interacting with big data anywhere, anytime," *IEEE Computer Magazine*, vol. 46, no. 4, pp. 86–89, Apr. 2013.

[2] F. Gebara, H. Hofstee, J. Hayes, and A. Hylick, "Big data textoriented benchmark creation for hadoop," *IBM Journal of Research and Development*, vol. 57, no. 3/4, pp. 10:1–10:6, May-Jul. 2013.

[3] J. Dean and S. Ghemawat, "MapReduce: Simplified data processing on large clusters," in *Proc. of 6th Symposium on Operating Systems Design and Implementation*, San Francisco, USA, Dec. 2004, pp. 137–150.

[4] "Hadoop [Online]." Available: http://hadoop.apache.org/.

[5] K. McKusick and S. Quinlan, "GFS: Evolution on fast-forward," *ACM Queue Magazine*, vol. 7, no. 7, pp. 1–11, Aug. 2009.

[6] K. Suto, H. Nishiyama, X. S. Shen, and N. Kato, "Designing P2P networks tolerant to attacks and faults based on bimodal degree distribution," *Journal of Communications*, vol. 7, no. 8, pp. 587–595, Aug. 2012.

[7] S. Ghemawat, H. Gobioff, and S.-T. Leung, "The google file system," in *Proc. of 19th Symposium on Operating Systems Principles*, New York, USA, Oct. 2003, pp. 29–43.

[8] A. Verma, L. Cherkasova, and R. H. Campbell, "Orchestrating an ensemble of MapReduce jobs for minimizing their makespan," *IEEE Transactions on Dependable and Secure Computing*, vol. 10, no. 5, pp. 314–327, Sept.-Oct. 2013.

[9] M. Cardosa, A. Singh, H. Pucha, and A. Chandra, "Exploiting spatiotemporal tradeoffs for energy-aware MapReduce in the cloud," *IEEE Transactions on Computers*, vol. 61, no. 12, pp. 1737–1751, Dec. 2012.

[10] Y. Zhang, Q. Gao, L. Gao, and C. Wang, "Priter: A distributed framework for prioritizing iterative computations," *IEEE Transactions on Parallel and Distributed Systems*, vol. 24, no. 9, pp. 1884–1893, Sept. 2013.

[11] D. Warneke and O. Kao, "Exploiting dynamic resource allocation for efficient parallel data processing in the cloud," *IEEE Transactions on Parallel and Distributed Systems*, vol. 22, no. 6, pp. 985–997, Jun. 2011.

[12] M. Asahara, S. Nakadai, and T. Araki, "LoadAtomizer: A locality and I/O load aware task scheduler for MapReduce," in *Proc. of IEEE 4th International Conference on Cloud Computing Technology and Science*, Taipei, Dec. 2012, pp. 317–324.

[13] A. Rabkin and R. H. Katz, "How hadoop clusters break," *IEEE Software Magazine*, vol. 30, no. 4, pp. 88–94, Jul.-Aug. 2013.

[14] H. Jin, X. Yang, X.-H. Sun, and I. Raicu, "Large-scale distributed systems at google: Current systems and future directions," in *Keynote Speech at the 3rd ACM SIGOPS International Workshop Large Scale Distributed Systems and Middleware*, Montana, USA, OCT. 2009.

[15] "HDFS Fereration [Online]." Available: http://hadoop.apache.org/docs/ current/hadoop-project-dist/hadoop-hdfs/Federation.html.

[16] Q. Zheng, "Improving MapReduce fault tolerance in the cloud," in *Proc. of IEEE International Symposium on Parallel & Distributed Processing, Workshop and Phd Forum*, Atlanta, USA, Apr. 2010, pp. 1–6.

[17] J. Dean, "Adapt: Availability-aware MapReduce data placement for nondedicated distributed computing," in *Proc. of 32nd IEEE International Conference on Distributed Computing Systems*, Macau, Jun. 2012, pp. 516–525.

[18] H.-C. Hsiao, H.-Y. Chung, H. Shen, and Y.-C. Chao, "Load rebalancing for distributed file systems in clouds," *IEEE Transactions on Parallel and Distributed Systems*, vol. 24, no. 5, pp. 951–962, May 2013.

[19] F. Azzedin, "Towards a scalable HDFS architecture," in *Proc. of International Conference on Collaboration Technologies and Systems*, San Diego, USA, May 2013, pp. 155–161.

[20] J. Zhang, G. Wu, X. Hu, and X. Wu, "A distributed cache for hadoop distributed file system in real-time cloud services," in *Proc. of ACM/IEEE 13th International Conference on Grid Computing*, Beijing, China, Sept. 2012, pp. 12–21.

[21] Z. Yao, X. Wang, D. Leonard, and D. Loguinov, "Node isolation model and age-based neighbor selection in unstructured P2P networks," *IEEE/ACM Transactions on Networking*, vol. 17, no. 1, pp. 144–157, Feb. 2009.

[22] W. Xiao, M. He, and H. Liang, "Cayleyccc: A robust P2P overlay network with simple routing and small-world," *Academy Publisher Journal of Networks*, vol. 6, no. 9, pp. 1247–1253, Sept. 2011. [1] Chia-Mu Yu, Guo-Kai Ni, Ing-Yi Chen, Erol Gelenbe, Life Fellow, IEEE, and Sy-Yen Kuo, Fellow, IEEE Top-*k* Query Result Completeness Verification in Tiered Sensor Networks Chia-Mu Yu, Guo-Kai Ni, Ing-Yi Chen, Erol Gelenbe, Life Fellow, IEEE, and Sy-Yen Kuo, Fellow, IEEE

[2] R. Agrawal, J. Kiernan, R. Srikant, and Y. Xu, "Order preserving encryption for numeric data," in *Proc. ACM SIGMOD*, 2004, pp. 63–574.

[3] A. Boldyreva, N. Chenette, Y. Lee, and A. O'neill, "Order-preserving symmetric encryption," in *Proc. Annu. Int. Conf. Theory Appl. Cryptograph. Tech.*, 2009, pp. 224–241.

[4] A. Boldyreva, N. Chenette, and A. O'neill, "Order-preserving encryption revisited: Improved security analysis and solutions," in *Proc. Int. Cryptol. Conf. CRYPTO*, 2011, pp. 1–18.

[5] M. Burkhart and X. Dimitropoulos, "Fast privacy preserving top-k queries using secret sharing," in *Proc. 19th ICCCN*, 2010, pp. 1–7.

[6] D. Boneh, C. Gentry, B. Lynn, and H. Shacham, "Aggregate and veriably encrypted signatures from bilinear maps," in *Proc. Int. Conf. Theory Appl. Cryptograph. Tech. Adv. Cryptol.*, 2003, pp. 416–432.

[7] M. Bellare and S. K. Miner, "A forward-secure digital signature scheme," in *Proc. 19th Annu. Int. Cryptol. Conf. Adv. Cryptol.*, 1999, 431–438.

[8] F. Chen and A. X. Liu, "SafeQ: Secure and efficient query processing in sensor networks," in *Proc. 24th IEEE Conf. Comput. Commun.*, Mar. 2010, pp. 1–9.

[9] C. Dwork, "Differential privacy," in *Proc. ICALP*, 2006, pp. 1–12.

[10] P. Desnoyers, D. Ganesan, and P. Shenoy, "TSAR: A two tier sensor storage architecture using interval skip graphs," in *Proc. ACM 3rd Int. Conf. Embedded Netw. Sensor Syst.*, 2005, pp. 39–50.

[11] E. Gelenbe, G. Görbil, D. Tzovaras, S. Liebergeld, D. Garcia, M. Baltatu,*et al.*, "NEMESYS: Enhanced network security for seamless service provisioning in the smart mobile ecosystem," in *Proc. ISCIS*, Oct. 2013, pp. 369–378.

[12] E. Gelenbe and G. Loukas, "A self-aware approach to denial of service defence," *Comput. Netw.*, vol. 51, no. 5, pp. 1299–1314, 2007.

[13] [Onllie]. Available: http://www.hpl.hp.com/news/2009/octdec/ cense.html

[14] Y.-C. Hu, A. Perrig, and D. Johnson, "Packet leashes: A defense against wormhole attacks in wireless networks," in *Proc. 22nd Annu. Joint Conf. IEEE Comput. Commun. INFOCOM*, Apr. 2003, pp. 1976–1986.

[15] H. Kido, Y. Yanagisawa, and T. Satoh, "An anonymous communication technique using dummies for location-based services," in *Proc. ICPS*, Jul. 2005, pp. 88–97.

[16] Q. Li and D. Rus, "Global clock synchronization in sensor networks," in *Proc. IEEE Conf. Comput. Commun. INFOCOM*, Jan. 2004, pp. 1–11.

[17] D. Ma and G. Tsudik, "A new approach to secure logging," *ACM Trans. Storage*, vol. 5, no. 1, pp. 1—3, 2009.

[18] J. Nesome, E. Shi, D. Song, and A. Perrig, "The sybil attack in sensor network: Analysis & defense," in *Proc. 3rd Int. Symp. ISPN*, Apr. 2004, pp. 259–268.

[19] B. Parno, A. Perrig, and D. Johnson, "Distributed detection of node replication attacks in sensor networks," in *Proc. IEEE Symp. Security Privacy*, May 2005, pp. 49–63.

[20] A. Perrig, R. Szewczyk, V. Wen, D. Culler, and D. Tygar, "SPINS: Security protocols for sensor networks," in *Proc. ACM Conf. Mobile Comput. Netw.*, 2001, pp. 521–534.

[21] L. Sweeney, "*k*-Anonymity: A model for protecting privacy," *Int. J. Uncertainty, Fuzziness Knowl. Based Syst.*, vol. 10, no. 5, pp. 557–570, 2002.

[22] B. Schneier and J. Kelsey, "Cryptographic support for secure logs on untrusted machines," in *Proc. 7th USENIX Security Symp.*, 1998, pp. 53–62.

[23] B. Sheng and Q. Li, "Verifiable privacy-preserving range query in two-tiered sensor networks," in *Proc. 24th IEEE 27th Conf. Comput. Commun.*, Apr. 2008, pp. 743–766.

[24] B. Sheng, Q. Li, and W. Mao, "Data storage placement in sensor networks," in *Proc. 7th ACM Int. Symp. Mobile Ad Hoc Netw. Comput.*, 2006, pp. 344–355..