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Systematic Review of Mobile Database Systems for Green Mobile Computing Ecosystem

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ABSTRACT

Access to essential and corporate information through mobile devices has become a routine activity. Vehicle navigation systems, like audio systems, are becoming standard equipment. These devices are very handy and user-friendly and such users can access needed information from databases from any location, anytime utilizing wireless and cellular communications. This study systematically reviews Mobile Database Systems for Green Mobile Computing Ecosystem. 343 papers where sourced. 42 of them made it to the final stage. 341 were excluded based on title and abstract. We presented the review in a table. 90% of the work focused on MDS and 10 on GMC. The study shows that Green Mobile Database Systems has very few literatures and it is a promising research niche.

Keywords: Mobile database Systems, Database, Green Computing, Mobile Computing, Green Mobile Computing

1.0 BACKGROUND

The history of computing has been marked by five major and continuing trends (Wooldridge, 2002): **ubiquity** (existing everywhere-omnipresent), **interconnection** (shift from a single high-processing computer to a highly distributed network of computers that can be geographically dispersed-internet), **intelligence** (embedding reasoning, learning, and thinking computers that can do operations that humans can do), **delegation** (now computer virtually does everything for humans), **human-orientation** (now users define and determine what and how a computational entity needs to be developed). Mobile computing is an area that these trends can are rapidly manifesting. Access to essential and corporate information through mobile devices has become a routine activity. Vehicle navigation systems, like audio systems, are becoming standard equipment. These devices are very handy and user-friendly and such users can access needed information from databases from any location, anytime utilizing wireless and cellular communications (Kumar, 2006).

Databases are conventionally processed by stationary processing units, such as servers or clients. Processing requests are brought to these processing units and they have fixed spatial coordinates. Both the processing units and their users are immobile throughout data processing in this model. This model of information management has several inherent inadequacies, resulting in unacceptably low productivity and unscalable because it cannot keep up with today's information processing needs.

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A new model of information processing needs and demands has emerged and still emerging as a result of recent changes in social structure, the desire for stronger connectivity among national and international communities and increasing geographical mobility of processing entities. One of the most significant parts of these requirements is that a user must be free of temporal and spatial constraints when processing data, which can only be done through geographic mobility during data processing thus mobile database system.

A Mobile Database System (MDS) is a system that combines database and mobile communication capabilities. It allows a mobile user to initiate transactions from anywhere and at any time, and it ensures that they are executed consistently. MDS ensures database recovery in the event of any type of failure (transaction, system, or media). (Kumar, 2006; Salem & Al-Qeerm, 2015). Let us consider some examples. Someone requesting for a bolt ride at Ajuru University will have different result with another query at Trans-Amadi Industrial Layout. Again, a query of the best restaurant to have continental dishes in Elelenwo will obviously not give us the same result as when the user is in University of Port Harcourt. Interestingly, the uniqueness and variations of the query results are due to the mobility of the database clients (smart phones, PDAs, handheld, etc), contextualization of the queries and the inherent nature of cellular networks. An MDS is therefore a distributed multi-database client-server system in which the client is mobile (e.g., operates on a laptop, PDA, or smart cellular phone, or handhelds), the server is static, the client has intermittent connectivity, and the client self-identifies its position (possibly via GPS), and the queries are often “location aware” (e.g., locate the nearest hospital). Database capability is provided by a group of DBSs (database servers) that are integrated into the generic mobile network without impacting any part of it.

A cellular (mobile) network with a fixed Mobile Support Station (MSS or server) that supports all mobile hosts (MHs or clients) travelling within its cell is the backbone of MDSs. When an MH exits one cell and joins another, it is no longer able to interact with the previous cell's MSS and is instead controlled by the new cell's MSS. A fixed network links all MSSs (Bernard et al., 2004).

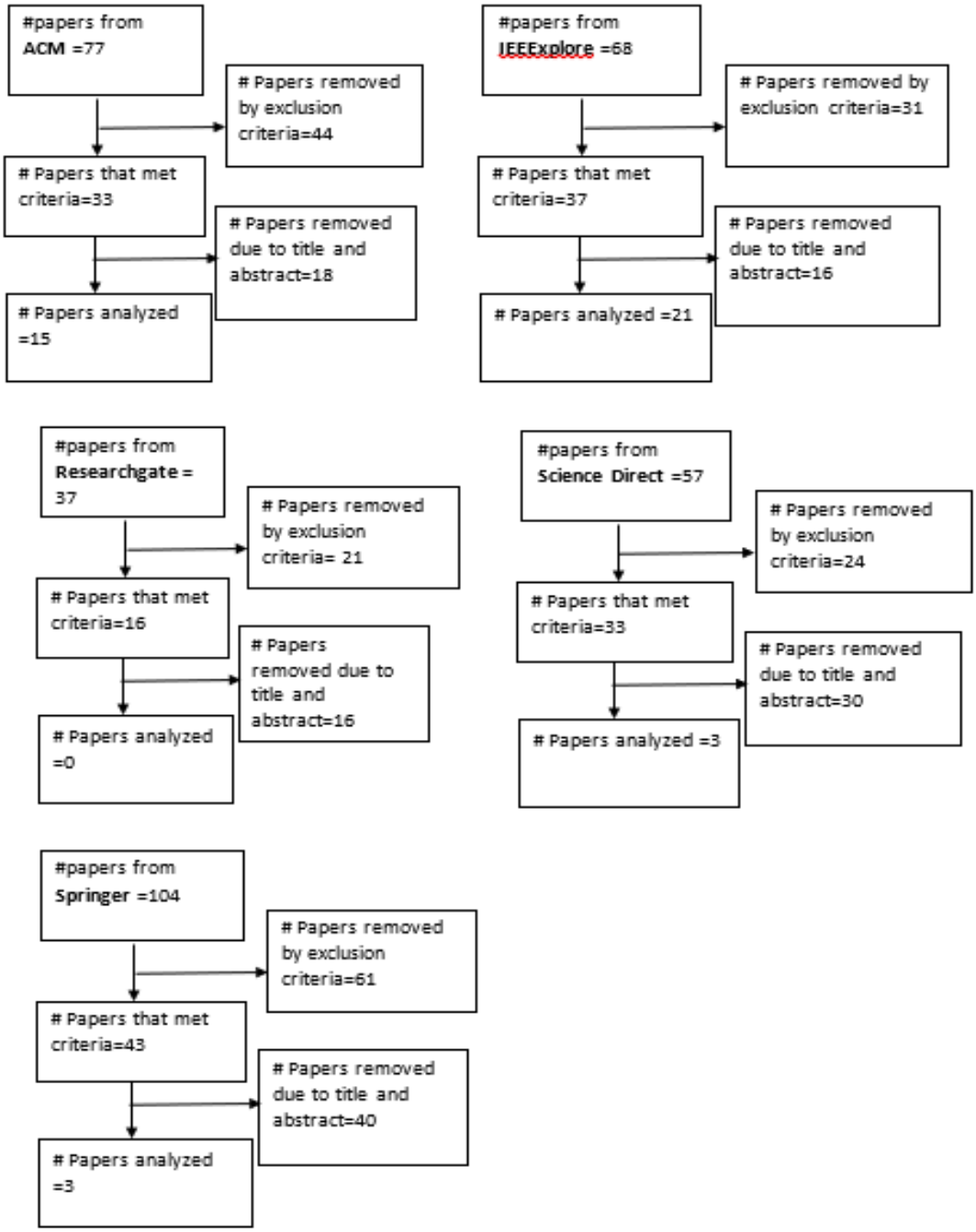
Bernard et al., (2004) posited some issues associated to MDS such as transaction management, data caching, data replication, and location-aware query processing. The research community has attempted to address these issues. Other issues mentioned by (Bernard et al., 2004; Serrano-Alvarado et al, 2004) includes mobility issue, limited memory and storage, intermittent disconnection, and energy consumption limitation in variety of ways, security and privacy principally in terms of detecting malicious transactions and maintaining privacy in location-aware queries.

As mentioned in (Bernard, et al., 2004; Serrano-Alvarado, et al, 2004), energy consumption limitations is one of the issues in MDS. Recall that mobile communication has evolved and it is still evolving with so much energy- hungry technologies. Inherently, processing of data in MDS depends on cellular communication. Another inherent issue that is energy related is database instance replications (multiple instance storage). Recall that for every client in MDS, a cache (a local database) is kept to store frequently used data and transactions so that they are not lost if the connection fails. This duplication mechanism will eventually result to additional consumption of energy from both ends of the communication (client-mobile and server(s)).

From the forgoing, several collaborative researches have emerged and still emerging which brings convergence of Database research community especially (Mobile Database ecosystem) and green computing research community to create ecofriendly MDSs. Green Computing is a computing paradigm where: (a) IT resource efficiencies are maximized, (b) resources (in particular, energy) are re-used whenever possible, (c) sustainable products and manufacturing practices are adopted, and (d)

green initiatives in other industries are supported through monitoring and management tools (Abbasi, et al., 2013; Shuja et al., 2017).

Figure 1: PRISMA process of data collection and analysis



Smart mobile devices from recent times have comparatively large storage capacities and enough processing power to handle resource-intensive tasks. Smart mobile devices users' preferences have reduced the need for desktop servers to execute all computer functions. As a result, Smart mobile devices application resource requirements have also amplified (Li, et al., 2010). Sensors such

as GPS, accelerometers, and wireless radios are commonly triggered by new media-rich smartphone applications to deliver context-aware services. As a result, the cost of computing, connectivity, and energy for smartphones has increased dramatically. Energy-efficient system designs are required to fulfill the requirements of modern Smart mobile devices in order to handle the energy-performance quid pro quo (Ahmad, et al., 2015). Thus, this study seeks to systematically review Mobile Database Systems for Green Mobile Computing Ecosystem.

2.0 Method

The approach of reporting for systematic review and meta-analysis proposed in (Moher, et al., 2009) was preferred for this review. PRISMA's data collecting and processing procedure is depicted in Figure 1. The PRISMA flow diagram depicts the many stages of systematic review. The flow of data collection and processing is depicted in Figure 1.

2.1 Research question

To determine how Mobile Database Systems can interleave with Green Computing to produce and manage MDSs that are energy-efficient.

2.2 Inclusion and exclusion criteria

Original publications dealing with Mobile databases Systems for green mobile computing ecosystem were included in this study. Non-English papers, as well as those for which the complete text was unavailable, and those that were published in any format other than original papers, were excluded (conference abstracts, review papers, letters, etc.). Literature reviews and surveys are also excluded.

2.3 Strategy

The databases searched were IEEE Xplore, ACM digital library, ScienceDirect, Springer, and Research gate. The examination was carried out between 10 January and 20 January 2021. The search string (population(P: Mobile Database Systems), intervention(I: green mobile computer), comparison(C) and outcome were defining using the PICO criteria (Petticrew & Roberts, 2008) (O). The comparison was excluded and the results were all publications using green Mobile Database Systems considerations. The review period is 2015 to January 2021.

2.4 Selection Process

Some relevant documents were chosen thoroughly screened by title and abstract. Table 1 shows list of papers analyzed with their focuses and key MDS issues they address.

Table 1: Selected Papers with their focuses and key issues they addressed

Study	Focus and Comments/key issues
Vidhya, et al., (2016)	Discussed what green computing is and the concept and design of a proposed Data Center. The focus is on green server. MDS and GMC not addressed
Peng, et al., (2015)	mainly studied minimization problem of energy consumption in data transmission under the given data generation rate and transmission delay demand in wireless links. MDS not covered

(Salem & Al-Qeerm, 2015)	Details which help to create a framework for classifying mobile database system transactions
(Gupta & Shanker, 2020)	Proposed a multi-level caching to protect an individual's location & his information to untrusted entity during mobility. GMC not addressed and focus on mobile
(Gupta & Shanker, 2018)	To ensure the efficient cache use, they proposed a system that took into account the key factors for cache replacement data items such as probability, query rate, customer update rate, cache location and cache direction, in order to increase cache replacement policy effectiveness.
Cai et al., 2020	The work proposed a way to improve protocols in MDSs by using embedded competition control technology. The two standard protocols, the Two-Phase Locking (S2PL) server-based protocol and the Call-back-Locking (CBL), were performed by them. They were compared with each other. No mentioned result.
(Lai et al., 2019)	The article proposes the VANET's adaptive, cloud-based consultation processing scheme that incorporates the node concept and integrates the cloud and vehicle networks to facilitate data storage, and indexing so that queries across different communication channels can be processed and transmitted based on cost and time of queries.
Choi, 2018	Legacy Project: SSD for SQLite. Didn't address GMC
Kobiela, (2020)	Addresses how to manage vulnerabilities of corporate data on mobiles. GMC not addressed
Li et al., (2016)	The study showed a set of innovative "Role Based Security Labware for Emerging Database Systems (REALAB) " deployed for teaching real-world mobile and NoSQL database security issues
Liu et al., 2016	Design of a "Lasagna" system for semantically managing and searching motion data. A prototype has been implemented, and evaluations show that the system can achieve very precise (98:9 per cent accuracy) and search activities over a variety of activities (around 100 per cent recalls and approximately 90 per cent accuracy).
Oh et al., 2015	Focused on SQLLite Optimization with Phase change memory. GMC not addressed
Papadopoulos et al., 2015	Proposed a remote application calling (RAC) for mobile collaboration
Park et al., 2017	In order to ensure that SQLite is truly ready for IO efficiency transactional support, SQLite/SSL, the SQL Statement logging system per transaction, has been suggested, ensuring durability to a transaction by saving SQL declarations in small sizes only and thus writing less quickly and without compromise on transactional strength.
Qian, et al., 2017	Presented an scheme for Secure Mobile Software Development (SMSD) through real-world-scenario case studies that relies on MDS
Tuan et al., 2016	Studied the IO characteristics of SQLite transaction in Android platform
Fernandes et al., 2015	Developed mobile app used to collecting health data using MDS
Gupta, 2020	Discussed the issues, challenges and new approaches for locally-dependent cache disability replacement, prefetching, location protection and MM policies.
(Zhang et al., 2020)	The study proposed a method to investigate the forensic encryption of mobile databases on Android smartphones based on static testing, not restricted to a specific mobile application and automatic analysis capabilities.
Vaupel et al., 2016	presented a generic architecture supporting users to effectively use applications on-line as well as off-line.
(Mahali et al., 2018)	Smart Traffic Light was designed for a smooth priority route through Smart Traffic Light when crossing the highway. The proposed was named "Smart Traffic Light for IoT and mBaaS (mobile backend as a service). "

(Sathe & Deshmukh, 2016)	They proposed a tracking system that combines smart phone application with microcontroller-based system which is embedded with an acceleration sensing module and a navigation system. Uses MDS
(Hisham et al., 2019)	Used IOT, MDS and Sensors for waste management
(Dedeepya et al., 2018)	By integrating the sensor components with the Raspberry pi and alerting the users via mobile apps, the system monitor changes in factors like temperature, moisture, soil moisture. MDS (Raspberry pi -MySQL)
(Xu et al., 2016)	They have developed a hardware system which collects environment parameters such as temperature, humidity, PM2,5 and PM10. Through the WIFI protocol, the data is transmitted to a wireless router. A remote server exists to receive data via the Internet from sensor nodes and stored information in a database. For data querying, the computer client and the mobile customer are developed.
(Andrianto et al., 2020)	The study developed smart greenhouses for hydroponic farming based on the Internet of Thing (IoT) and MDS
(Alzughaibi et al., 2019)	They developed a framework that would enable crowd-sourcing readings from smart citizen distributed devices and distribute them in actionable information. The information can be given in the form of a disaster map, with buildings tagged by their probable damage state, to the public security personnel within minutes of the event.
(Roh et al., 2017)	Kaleido has been developed as a multi-device synchronization data system. Kaleido allows customers to synchronize replicated types of data with operations and ensures high availability and eventual consistency. The Kaleido server is implemented as a back-end service, so that a large number of requests are processed from huge customers.
(Zhang et al., 2015)	A macro-assisted data carrier proposed for future 5G networks from a green perspective. All key processes have been developed, such as small cell identification and access, timing, hand-over and small cell sleep. In addition, a complete simulation system and link-level platform was developed to evaluate the potential of the proposed scheme, in accordance with the existing LTE 3GPP standard.
(Yadav & Zhang, 2017)	They suggested an energy-aware heuristic adaptive algorithm that uses the most recent history for the detection of over-loaded hosts and dynamic algorithms for the selection of the VMs with the highest CPU usage. It seeks to reduce total energy consumption and maximize quality of service, including the reduction of service level agreements (SLAs). The algorithm has been validated by CloudSim Simulator and simulations in real workload tracks provided by PlanetLab were conducted within ten different days.
(Winderbank-Scott & Barnaghi, 2017)	They developed a wireless monitoring system for use within a pediatric environment. Utilised MDS
(Jiang et al., 2016)	The research investigated the power and energy properties of the six different platforms (3 mainstream 2U rack servers, one emerging ARM64 server, one desktop and one laptop) on the four mainstream hypervisory systems as well as the container engines, VMware ESXi, Microsoft Hyper V, KVM, XenServer and Docker with long periods of energy measurement.
(Lahiri et al., 2020)	Two key challenges have been highlighted, namely scalability and security problems. A BC is a public shared database recording transactions between two parties, which cryptographically confirm ownership. Once a transaction was validated and encrypted, it generated a block of the BC and chronologically ordered transactions without alteration. transactions were not modified. IoV security features will be provided by the implementation of BC and smart contract technologies.
(Halvorsen et al., 2018)	They presented a mobile alarm system for people based on data from various locations from the Norwegian Institute of Air Research (NIL U), along with www.yr.noin weather

	parameters as a push service available to anybody who has a username developed for the Webserver by students and staff of South-East Norway University for that purpose.
(Vimal & Shivaprakasha, 2017)	They developed an Arduino-based system that continuously updates and monitors the value of environmental parameters in order to achieve optimal plant growth and output. The main sensors used in the project include the DHT11 sensor, soil moisture sensor, LDR sensor and pH sensor. All environmental parameters are sent off-line and online to android mobile phones.
(Hsu et al., 2016)	The system is based on various layers of driving fatigue status and displays a warming message in red, yellow and green lights. It was used to alert the driver and record the data in the database with the mobile device. Furthermore, the system has a GPS positioning feature. After downloading to the cloud server, brainwaves and GPS data will be integrated and analyzed to remind drivers of dangerous drivers within 20 m.
(Nizami et al., 2018)	This research has developed a mobile application called the Clinical Event Notebook (mHealth) application (app) (CEA). A native Android tablet app and an administrative web application are included in the CEA. In patient's bedside, the indigenous app is used to manually record clinical events in real time. Patient monitor alarms, routine health care, clinical interventions, and patient movement are all types of events. The app can be updated dynamically with custom events defined by the user.
(Saradha et al., 2017)	They designed a mobile app that connects both ambulances and the traffic signal station using cloud network. Used for traffic management. Uses MDS
(Jagdale & Bakal, 2016)	They have developed a mobile application that links ambulances and the Cloud network traffic station. Used to manage traffic. You are using MDS They proposed an application and a dynamic protocol on clothing. They simulated the model of user privacy broadcasting in which mobile and POIs are fixed. The second test is a site privacy POI broadcasting model. We have also implemented a dynamic cloak protocol that considers the speed, direction and location of the mobile covering user
(Mokhtar et al., 2021)	The study developed a mechanism in order to find the optimal recovery solution using the best tool for game theory using state-of-the-art technology in MDS.
Ruby et al., 2019)	The study suggested that mobile database systems should have a hierarchical replication and multiversion competitive control model.
(Qayyum et al., 2015)	They suggested a cluster-based data replication technique for data reproduction and to overcome the problems of node mobility in the MANET area. Their approach consists of two phases; the first phase is cluster and cluster head formation and, in the third phase, the distribution of data (replicated data) to the cluster head respectively.

3.0 Results and Discussion

In this study, 43 articles were reviewed in detail. Table 1 summarizes the 42 papers with their focus areas. Figure 2 shows the distribution of the papers. 90% of the literatures focused mainly on MDS and 10% on GMC(Green Mobile Computing). Figure 3 gives the distribution of papers by source. 50% of the papers were sourced from IEEEXplore. 36% were sourced from ACM digital library, 7% from both Springer and ScienceDirect. No paper from Researchgate made it to the final stage. SQLLITE is the most studied MDS in academic literatures.

Figure 2: Paper Distribution

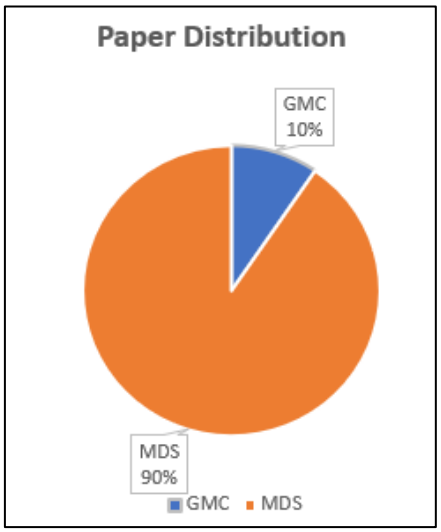
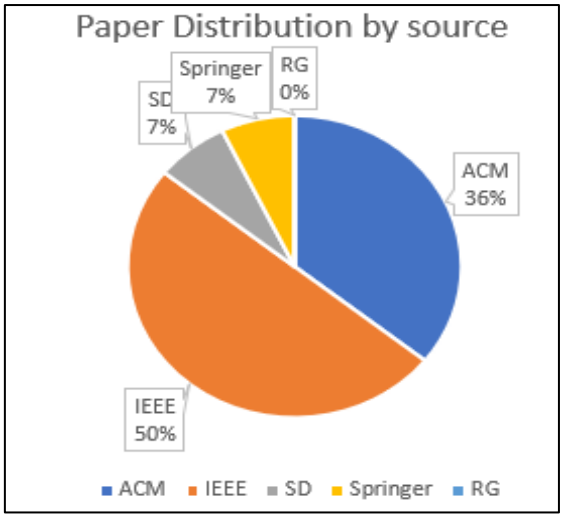


Figure 3: Paper distribution by source



4.0 Conclusion

Today the use of mobile host-related contextual information is increasingly evident in the trends that currently exist. Context-aware information requires an identification of a specific person's time, place and device identities. The potential sources of this information are a microphone, a camera, a web browser, a GPS receptor and the related server with a given entity. Location-based service is a context-sensitive application that can be defined as services integrating a cellular area or position with other data to give the customer enhanced value in the right time. As a result, the cost of computing, connectivity, and energy for smartphones has increased dramatically. Energy-efficient system designs are required to fulfill the requirements of modern Smart mobile devices in order to handle the energy-performance quid pro quo especially in the area of smart mobile databases (Ahmad, et al., 2015).

This review shows that there is huge research gap to be filled in achieving Green Mobile Database systems as there are very few literatures on this area.

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