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Distributed database on blockchain technology for new era of electricity transactions

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Abstract. The electricity retailers or suppliers promote business models focused on consumers-centred services except few of them. The reader could even doubt their interest in offering the most appropriate tariffs since lower tariffs imply lower revenue and consequently lower profit. No one-fit-for-all service can actively engage the electricity consumers. Most of the electricity consumers do not understand their consumption behaviour because they do not know it, they do not have real access to the consumption data. The current web portals do not share the consumption data with third parties, thus there is no market solutions. In this paper, we propose a distributed database architecture on blockchain technology for electricity transactions that innovate and increase the market competition in the era of digitalization enhancing the consumers awareness and transparent transitions.

1. Introduction

The conventional electricity flows that come from large power plants via transmission and distribution grids to the final consumers have changed since the distributed generation, storage systems, demand side management and other technologies evolved.
The blockchain technology is a trading solution that increases the market competition and encourages peer-to-peer transactions among electricity consumers. In the current centralized market platforms, only the generators and suppliers can notify offers and trade. Then the suppliers sell the electricity to the final consumers at higher prices that include tariff and distribution and components. Also, the price includes the profit component to ensure the sustainable development of the suppliers' activities. In this context, the consumers or prosumers are not able to interact, trade and benefit from the market mechanisms even though they have a surplus from PV panels or other generation sources. Peer-to peer transactions will considerably lower the electricity price and foster the market competition.
Distributed databases that could be a data storage solution for electricity transactions consist in logically interconnected data collections stored according to a data model distributed among several network nodes [1], [2] that appear to the user as a single database [3], [4]. The first databases were locally installed and accessed. Then, the centralized databases accessed from distance by means of computer networks. They were followed by the Distributed DataBases (DDB) with data stored in nodes and accessed from anywhere. Then, the databases have been accessed in cloud as alternatives for centralized or DBB. The DDB concept has been retrieved and extended to large data processing (parallel data processing and distributed over multiple nodes).
DataBase Management System (DBMS) for DDB have similar objective with any DBMS (as in Figure 1) with some particularities obvious for DBB specificity.

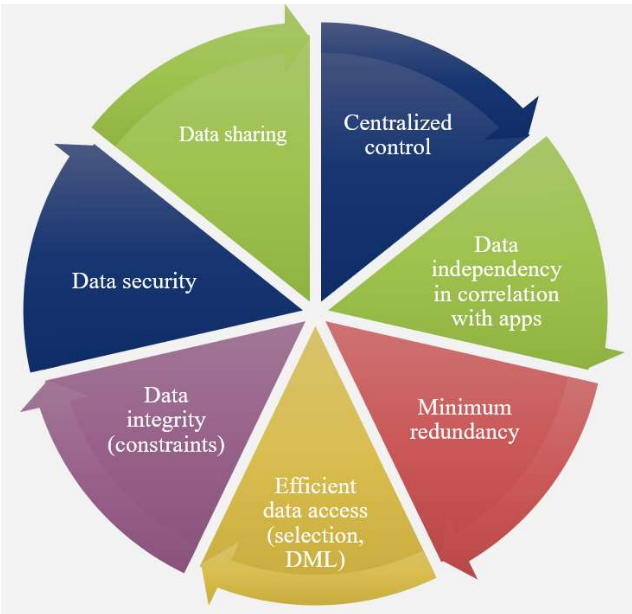

Fig. 1. Database Management System objectives

The main differences between centralized DB and DDB can summarized as in Figure 2

Fig. 2. DDB particularities

2. Data Distribution Techniques

Data collections can be distributed in several physical locations or nodes by means of data distribution techniques, such as: fragmentation, replication, mixed distribution and data distribution by loading [5-7].

2.1 Fragmentation

- Fragmentation distribution involves the logical decomposition of data into fragments based on a fragmentation scheme and rules, such as:
  - Completeness: any tuple in a relationship is found in a single fragment, so that data is not lost to fragmentation;
  - Reconstruction: any relationship can be reconstituted from its fragments, guaranteeing the maintenance of functional dependencies;
  - Disjunction: fragments in which a relationship breaks down must be exclusive; it applies less for attributes with the primary key restriction.
- Fragmentation is accomplished by projection and selection operations, by three fragmentation methods: horizontal, vertical and mixed (as in Figures 3-5).

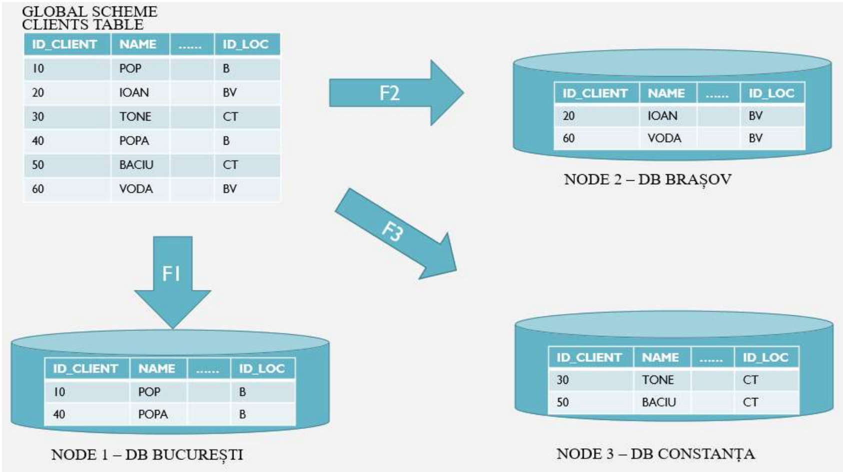

Fig. 3. Horizontal fragmentation

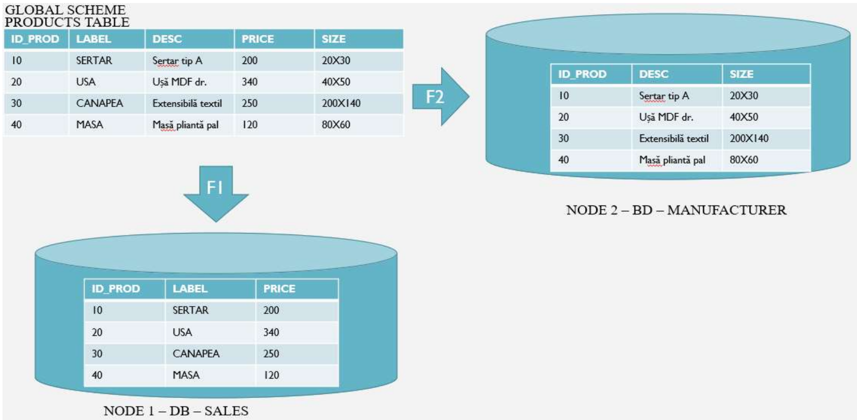

Fig. 4. Vertical fragmentation

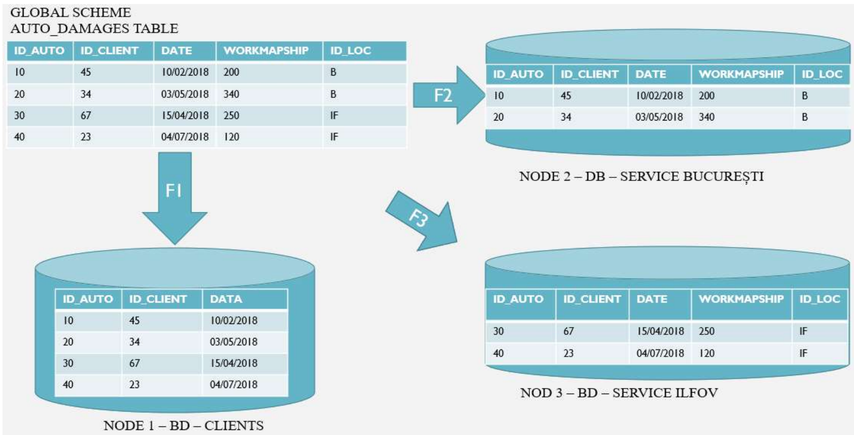

Fig. 5. Mixed fragmentation

2.2 Replication

It assumes the storage of portions from a database in the form of copies on multiple nodes. When a user updates a local data set, the Distributed Database Management System (DDBMS) will automatically update all copies. Data may be non-replicated, partially replicated or replicated altogether. The degree of replication is influenced by the database size, the available computing and storage resources, and the frequency of types of operations.

2.3 Mixed data distribution

It involves sequential application of fragmentation and replication techniques. Data may first be fragmented, then one or more fragments are replicated, or the data may initially be replicated, and one of the copies may be fragmented. It presents the advantages of the two techniques, but is more difficult to implement.

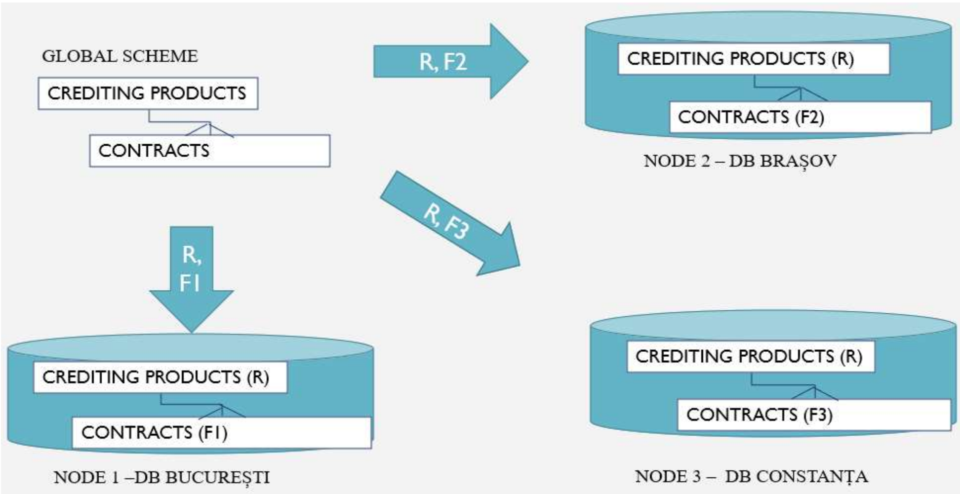

Fig. 6. Mixed distribution

2.4 Data distribution by loading

It is the periodical copy operation of the entire database or portions of it from the local nodes. The upload technique is considered to be the easiest to implement, but it is recommended to use it when the data is not frequently updated.

DDBMS are complex systems that manage DDB consisting in several local databases integrated into a communications network. The DDBMS promotes a two-tier architecture: the global level and the local level. DDBMS s may be homogeneous (if local SGBDs are of the same type) or heterogeneous.

3. Oracle Database Distribution Techniques

Oracle Database uses the following distribution techniques:

- Links between local BD (database link, as in Figures 7-9);
- Read-only snapshot / materialized view;
- Updateable snapshot with:
  - synchronous multi-master replication;
  - asynchronous multi-master replication.

Database links between Oracle Database and other DBMSs such as MySQL or SQL Server are created using a connection to users (user_payroll and user_commercial). Queries and data manipulation operations are allowed using the link name in case the DBMS are heterogenous (as in Figures 7 and 8). In Figure 9, a homogenous DDB architecture is presented. The management of replication and fragmentation techniques are performed by a Oracle Enterprise Manager Cloud 12c [8], [9].

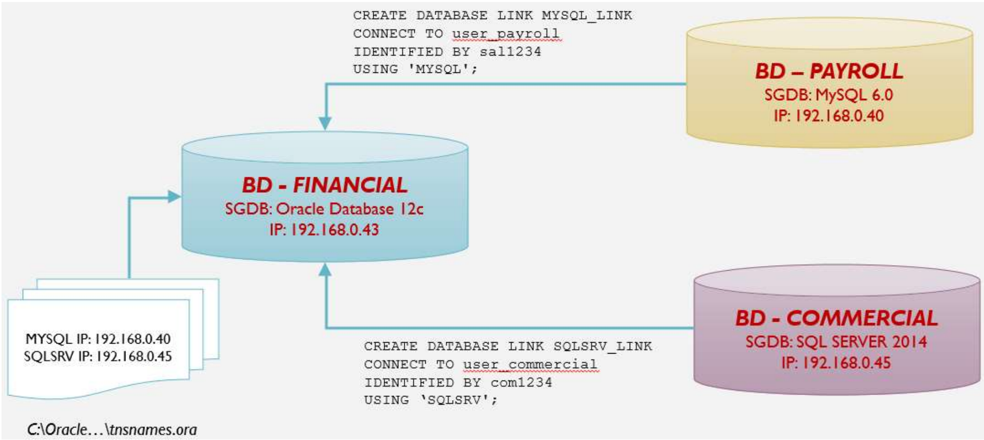

Fig. 7. Database link

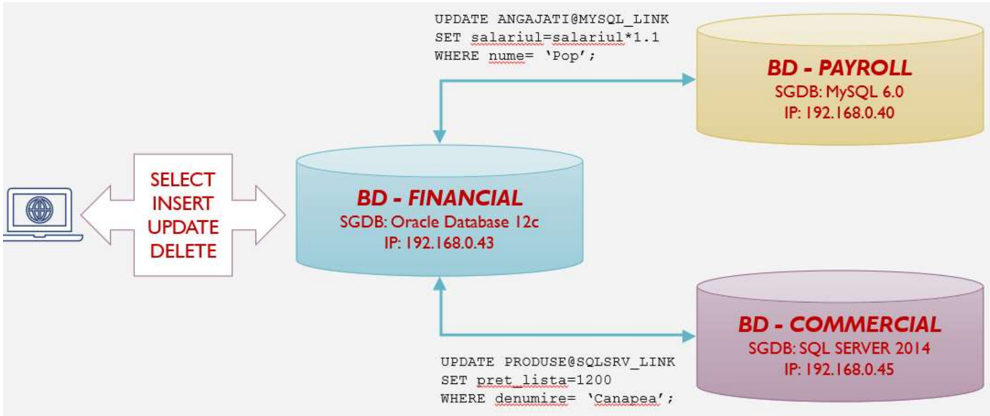

Fig. 8. Heterogenous nodes

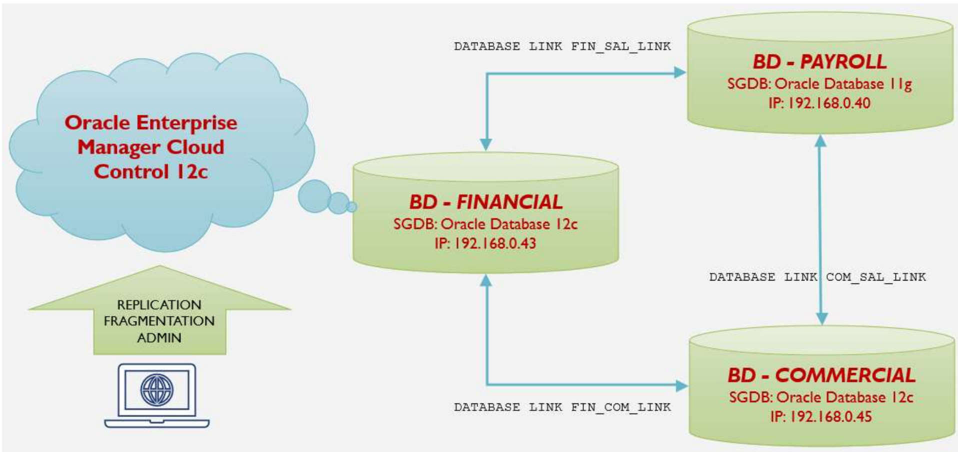

Fig. 9. Homogenous nodes with Oracle Enterprise Manager Cloud

4. Data allocation strategies

Assigning data to multiple stations within a computer network must take into account several factors:

- data must be stored as close as possible to where it is used frequently;

- data must be available even if a node is unavailable by replicating fragments at multiple nodes;
- involve minimal storage and communication costs.

The centralized strategy implies the existence of a single database and a single DBMS, both stored on a node, with users distributed over a network leading to low reliability.
The fragmentation strategy assumes that the database is fragmented into disjoint fragments, each fragment being assigned to a node. Since the fragments are not replicated, the storage costs are low and the reliability is limited.
The complete replication strategy involves keeping a complete copy of the database at each node; reliability and maximum performance, as well as maximum storage and communication costs for updates.
The selective replication strategy is a combination of fragmentation, replication, and centralization. Some of the tables in the database are fragmented, and others, which are used at multiple nodes and are not frequently updated, are replicated. The other tables can be centralized.

5. Data allocation strategies for electricity consumption

Considering the electricity consumers and the opportunity to trade and benefit from the market mechanisms, a simplified global scheme is shown in Figure 10. Starting from the above paragraphs, *consumption_place, smart_meters, metering_reads* could be fragmentated, while *electricity_consumers, tariff_schema, locations* and *transactions* could be replicated to each node.

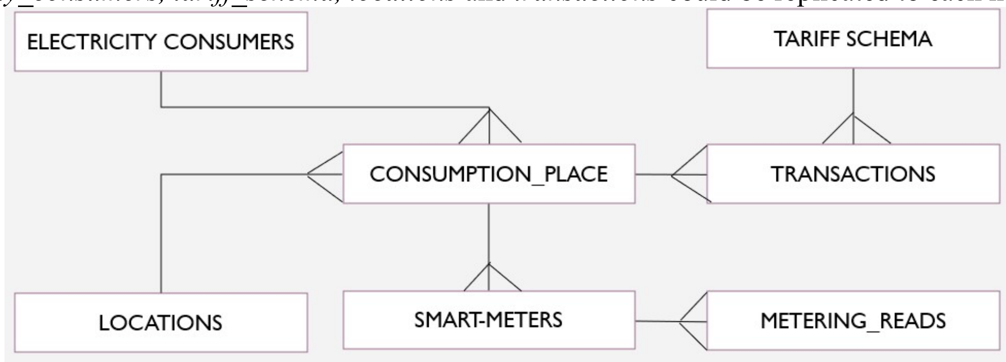

Fig. 10. Study case for electricity consumption

The DDB access should be permissioned or authorized so that only the interested parties could trade and share the resources of the transaction platform. The solution may start from local communities that could share the electricity.
A simple DDB architecture for electricity transactions is presented in Figure 11. It consists in three nodes that can be managed at the community or microgrid level or at consumers' level. The administrator of such platform could be the microgrid that could handle the electricity transactions within the microgrid and interactions with other microgrids or power grid. The replicated transactions can be only inserted (no modification or deletion is allowed) forming a transaction ledger that increase the trust among consumers and enhance the market competition. Monthly, the blockchained data could be trimmed since the settlement was already performed and the historical transactions are not relevant for real-time transactions. Several copies of the historical data could be stored but 100% replication of this data is not necessary.

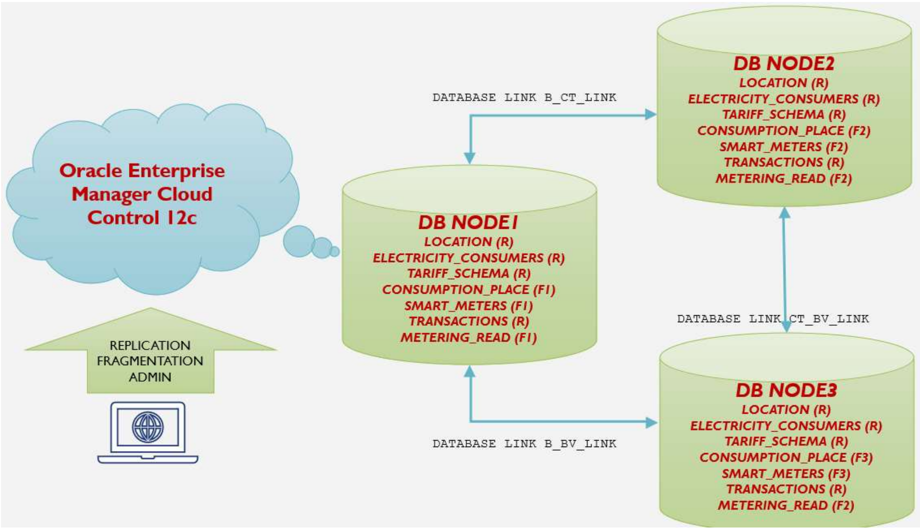

Fig. 11. DDB architecture for electricity consumption

Such blockchain architectures could be extended for larger communities. However, the new transaction mechanism impacts on the grid operator and suppliers and measures to lower the risk are envisioned to protect the development of these companies.

6. Conclusion

The current informatics solutions for electricity consumers do not share the consumption data with third parties, being a unidirectional process that does eliminate the competition. Therefore, in this paper, we proposed a distributed database solution on blockchain technology for market transactions that enhance the competition in the era of digitalization increasing the electricity consumers' awareness and involvement. The blockchain technology is a peer-to-peer trading solution that favours the market competition. In the centralized electricity market, only the producers and suppliers can trade. By means of a distributed database, the consumers or prosumers can benefit from the market mechanisms selling the electricity surplus from PV panels, micro-wind generators or other generation sources. Peer-to peer transactions considerably lower the electricity price considering that the additional costs and profit of intermediaries are avoided. Also, they encourage the distributed renewable generation integration increasing the local consumption and decreasing the electricity flows and the stress on public grid infrastructure. The main challenge is faced by grid operators and electricity suppliers in terms of designing new business models that should also consider the peer-to-peer transactions.

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