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Conceptual Modelling of Information Exchange Network for Nigeria Deregulated Electricity Market using Object-Oriented Approach

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ABSTRACT

Nigeria government has taken a major step towards the deregulation of her electricity power sector by separating the competitive segments from the naturally monopolistic segment. The unbundling of the vertically integrated system will require information exchange between the various organizations that will be involved in the network and market operations not only to maintain the integrity and reliability of the whole power system, but also for settlement purposes. However, it is not yet clear when the information infrastructure will be put in place. Here we present a conceptual model of the information exchange network for the deregulated electricity market using object-oriented approach. The paper presents the requirement, analysis and design models of the information network. The presented models make use of Unified Modelling Language (UML). Using object-oriented approach will enable the information network infrastructure to meet the requirements of flexibility, expandability, maintenance and data integrity that are very important for such new and evolving market. It is hoped that the presented information exchange model will serve as a good starting point for the development of information exchange network infrastructure for the electricity market operations in Nigeria.

Keywords: *Deregulated Electricity Market, Object-Oriented Analysis and Design, Information Exchange Network; Universal Modelling Language, Nigeria.*

1. INTRODUCTION

The Nigeria Electric Power Sector Reform Act (EPSRA) of 2005 [1] is transforming the electricity landscape in Nigeria into one where traditional monopolistic practices are being replaced by commodity transactions in an increasingly complex market. This transformation and restructuring however bring with it new challenges. Several market actors will be involved in the market operations and their decisions will be based on economics considerations. These decisions need to be considered in the management of the transmission systems physical aspects of power transmission [2] and data also must be exchanged for settlement and billing purposes. It is therefore very important that new information system and good communication infrastructures must be provided to take care of the exchange of information between the grid operator, the energy producers, transporters and retailers. The provision of these infrastructures is very important not only for the management and monitoring of system security, and reliability by the grid operators, but also for the accounting and settlement purposes.

Various countries across the world where deregulation has already taken place have put necessary information exchange infrastructures in place to support the network and market operations. The important role of information exchange in network operations has led to the adoption of Common Information Model (CIM) as standard for exchanging and managing network models by many electricity utilities all over the world [3-7]. There are also efforts to extend CIM to support electricity market communications [8, 9]. While the CIM standard can be adapted to cater for the exchange of network models in Nigeria electricity market environment, the information model for the market operations needs to be tailored towards the adopted market model in Nigeria as defined in Market Rules [10] and Grid Code [11]. In addition, the provision of powerful information infrastructure to automate the electricity transactions needs to be put in place.

Due to the evolving market operation coupled with several organisations that will be involved in the market, the information network for the market must be flexible, expandable, easy to maintain, be realised in an easy or automatic way as well as independent from organisation internal data model and applications. The information exchange system infrastructure must also be flexible enough to support all kinds of content sources, business rules, and the existing information technology infrastructures. The system must support all market actors including big, medium and small organisation.

The object-oriented paradigm seems to meet these requirements as it overcomes the problems of traditional software technology has with flexibility, expandability, maintenance and data integrity. This paper applies object-oriented approach to construct a conceptual model of information exchange network for Nigeria deregulated electricity market. The paper presents the requirement, analysis and design models of the information exchange network hereafter refers to as INFOXNET. It shows how the developed INFOXNET model is linked to the XML-based information exchange framework developed in [12]. We used object-oriented techniques [13] and Unified Modelling Language (UML) [14] for the development of the INFOXNET models. UML will be briefly explained with the basic concepts of object-oriented technique.

The rest of the article is organized as follows. Section 2 presents an overview of object-oriented modelling methods. Nigeria deregulated electricity market is discussed in section 3 while section 4 presents and discusses the information exchange network model. The paper ends with conclusions in section 5.

2. OVERVIEW OF OBJECT-ORIENTED APPROACH

Object-oriented approach regards a system as a set of interacting objects with messages passed between objects. An object is defined as a real-world physical or conceptual entity that provides an understanding of the real world and hence forms the basis for a software solution. A real-world object can have physical properties (they can be seen or touched); examples are transmission line, generator, or power transformer. A conceptual object is a more abstract concept, such as meter data or imbalance quantity. The term "object-oriented" means that software is organized as a collection of discrete objects that incorporate both data structure and procedures that operates on the data. The procedures are usually called operations or methods. The signature of an operation specifies the operation's name, the operation's parameter, and operation's return value. An object class describes a group of objects with similar properties (attributes), common behaviour (operations), and common relationships to other objects. Objects in a class have the same attributes and behaviour patterns. Objects derive their individuality from differences in their attribute values and their relationships to other objects [15, 16].

Object-oriented technique involves the building a model of an application domain and then adding implementation details to it during the design of a system [17]. It divides software development into four main phases:

- *Requirement*: A requirement model is developed in which the functional requirements of the system are defined in terms of actors and use cases. The result of this phase is a use case model.
- *Analysis*: This involves the modelling of the real-world system so that it can be understood. Using the use case model and the domain concepts, the objects and their relationships are identified. The emphasis at this stage is what to do, rather than how the problem is to be solved.
- *Design*: This phase includes the system and object design. The system design focuses on the designing the overall systems architecture, while the object design focuses on the refinement of the analysis model. The internal details of the objects, the algorithms to be used, business logic and the data structures form the central focus of this phase. Further more, the architecture of the system by considering the technology dependent components (e.g. database systems, communication between nodes for distribution application systems, hardware etc.) is determined. While the analysis phase describes what to do, the design phase specifies how the problem is to be solved.
- *Implementation*: The object classes and relationships developed during the design phase are finally converted to a program. The choice of the tools especially the programming language plays a very important role at this point.

UML provides various notations for describing each of the development phases. UML is a general-purpose language, which has emerged from the standardisation efforts within the Object Management Group (OMG) [18]. Various types of models can be used to describe the system being modelled during these phases. In this work, we used three different models for the description of the INFOXNET:

- Use Case Model
- Object Model
- Dynamic model

Each of the three models describes different aspects of a system. By modelling *meter* and its associated classes, these three models, and other concepts used in the context of this work are briefly explained using the UML notations.

2.1 Use Case Model

A use case defines a sequence of interactions between the actor and the system. The purpose of use case is to define a piece of coherent behaviour without revealing the internal structure of the system. A use case is a coherent unit of externally visible functionality provided by the system unit and expressed by sequences of messages exchange by the system unit and one or more actors of the system unit [19]. An actor normally initiates a use case. An actor is depicted as a stick figure on a use case diagram. A use case is shown as ellipse inside the box. Communication associations connect actors with the use cases in which they participate. Relationships among use cases are defined by means of stereotype *include* and *extend* (not applicable in this case) relationships. Stereotype is depicted by using guillemets << >>. The sending of meter data by a distribution company (Disco) to Market Operator (MO) is used to illustrate the concepts of use case. In this illustration, the Disco aggregates the meter data per supplier and sends the meter data to MO. The MO receives the meter data into its database and uses it later for the calculation of the imbalance quantity. The stereotype <<include>> relationship indicates that the Disco must aggregate the meter data before sending it to the market operator. Figure 1 shows the use case model for the sending of meter data. In this case, MO and Disco are the actors.

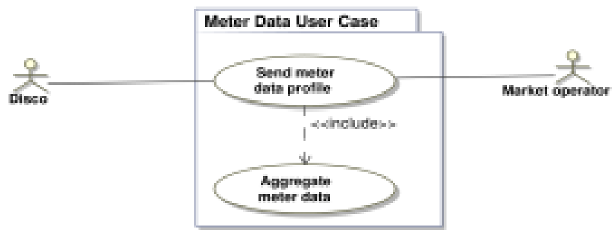


Figure 1: Example of use case diagram

2.2 Object Model

The object model describes the static structure of the system being modelled. It defines the classes of objects in the system, the attributes of the classes, the relationships between the classes, and the operations of each class. Object models are shown on class diagrams. A class diagram is a schema, pattern, or template for describing many instances of a data. In a class diagram, classes are shown as boxes and the static relationships between them are shown as arcs in the UML notation. The box holds the class name. Optionally, the attributes and operations of a class may also be shown. If all the three are shown, the top compartment of the box showing the class holds the class name, the middle compartment holds the attributes, and the bottom compartment holds the class operations. Relationships between the classes (associations) are shown as an arc joining the two class boxes, with the name of the association next to the arc. The multiplicity of association specifies how many instances of one class may relate to a single instance of another class. This is shown by numbers and stars at the end of an association path. The multiplicity may be one-to-one, one-to-many, numerically specified, optional, and many-to-many association. Figure 2 shows the object model for *Meter* class including its associations with other classes to illustrate these concepts. In the figure, objects of the class *Interval is* component of object of the class *Profile* which is shown by a black diamond adornment that touches the *Profile* class box. This form of association is called composition association. Composition association is a stronger form of *whole/part* relationship than the aggregation relationship. A hollow diamond adornment is normally used to show aggregation association (not used in this example). Composition and aggregation are special forms of relationship in which the classes are tightly bound by the whole/part relationship. Inheritance or generalisation is an *is-a* relationship. A generalisation is depicted as arrow joining the subclass (child) to superclass (parent), with the arrowhead touching the superclass box. The generalisation of the *MeterDataProfile class* to a general superclass *Profile* class is shown in figure 2.

2.3 Dynamic Model

The dynamic model describes the dynamic or behavioural aspects of a system. The purpose of the model is to assist in the determination of operations of the individual classes. UML provides various possibilities through which the dynamic behaviour of a system or use case can be investigated in order to determine the operations of the classes, such as sequence diagram, communication diagram, and statechart etc. The choice however depends on the problem to be solved. In this work, communication diagram for the analysis of the electricity market information network is used.

A communication diagram shows how the co-operating objects dynamically interact with each other by sending and receiving messages in order to fulfil the functionality of a system or a use case. Objects are shown as boxes, and arcs joining boxes represent object interconnection. Labelled arrows adjacent to the arcs indicate the name and direction of message transmission between objects. A message consists of an event together with data that accompanies the event, referred to as the attributes of the message. The sequence of messages passed between the objects is numbered. Multiple messages can be attached to the same link between two objects, in the same or opposite directions. Figure 3 shows the UML notation for communication diagram for *Send Meter Data* use case. The numbers show the nested calling sequence. At this point the internal details of the *Information Network* are not shown.

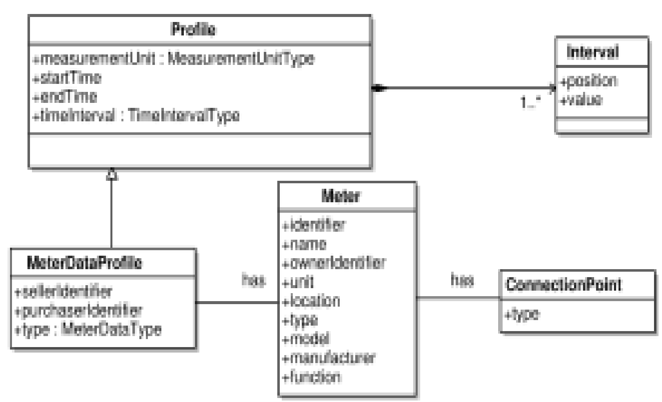


Figure 2: Example of object model showing meter and its associated classes

3. NIGERIA DEREGULATED ELECTRICITY MARKET

The Nigeria electricity supply industry is made up of single vertically integrated utility - Power Holding Company of Nigeria (PHCN) formally called National Electric Power Authority (NEPA). PHCN is responsible for generation, transmission and distribution of electricity to various types of consumers – industrial, commercial and residential. The transmission system supplies bulk power from the generators to the distribution substations at high voltages (132 - 330KV) while the distribution system delivers power from these substations to the consumers' doorstep predominantly at various low voltages (33KV, 11KV, 415V and 220V) [12].

Through the Nigeria Electric Power Sector Reform Act (EPSRA) of 2005 [1], PHCN has been separated into generation, transmission and distribution companies. The Act stipulates the functional unbundling of the Generation, Transmission and Distribution sectors. The unbundling of PHCN has resulted into 6 generation, one transmission and 11 distribution successor companies. EPSRA provides an enabling regulatory framework for private sector participation in the electricity industry in Nigeria. The Act stipulates the establishment of a regulatory body - National Electric Reforms Commission (NERC) to facilitate the privatisation of the successor companies as well as the gradual development of a competitive and privately managed electricity sector. 6 Generation companies (Gencos), 11 Distribution companies (Discos) and one Transmission company (TCN) are created from the existing vertically PHCN utility. The functions and responsibilities of the successor companies operating at the generation, transmission and distribution section are clearly specified in the Act. The operations of the Discos are restricted to the coverage of their specific geographical zones in Nigeria, and they are commercially and administratively responsible for their coverage areas, while the Gencos are responsible for operating their power stations, improving the generation capacity and making the necessary investments in line with the objectives of the Federal Government of Nigeria.

To guarantee non-discriminatory access to the transmission system, the competitive segments will operate in accordance with the Market Rules [10] and Grid Code [11]. The competitive segments will be overseen by the Market Operator (MO) and System Operator (SO) under the regulatory supervision of the Nigeria Electricity Regulatory Commission (NERC). The Metering [20] and distribution code [21] have also been published to take care of the metering and distribution aspects of electricity. Figure 4 shows the object-oriented representation of the relationship between the various entities in the new Nigeria deregulated electricity market.

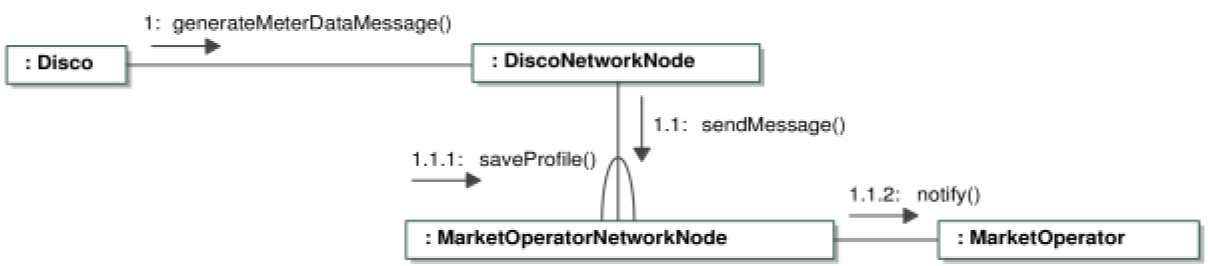


Figure 3: Example communication diagram

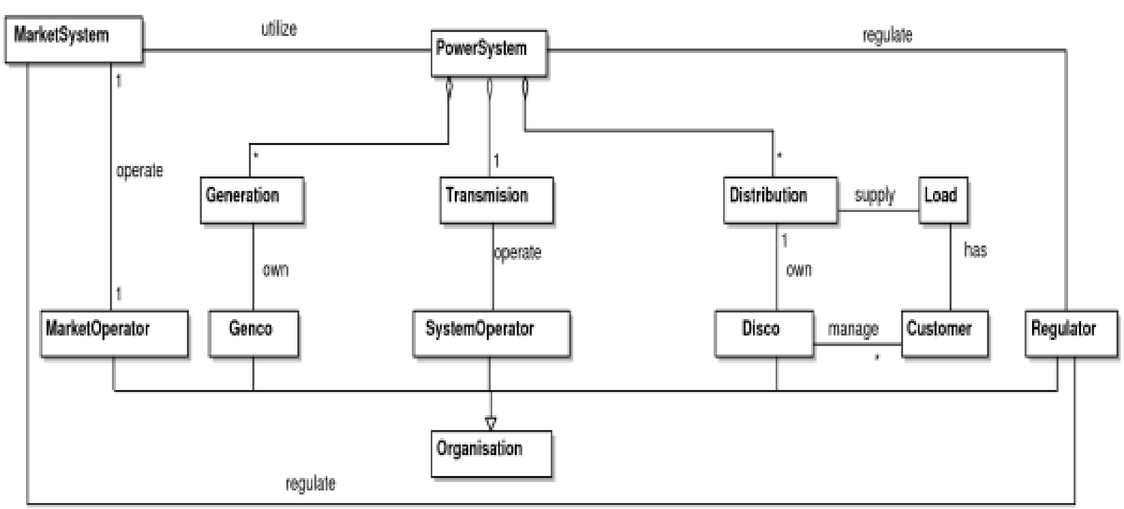


Figure 4: Object-oriented representation of Nigeria deregulated electricity market.

4. RESULTS AND DISCUSSION

We present and discuss the model of the INFOXNET including requirement, analysis and design model as well as the implementation of the INFOXNET.

4.1 Requirement (Use Case) Model

The Nigeria deregulated electricity market operation as described in section 3 will be characterised by the following basic processes:

- Exchange of basic data
- Evaluation of transmission constraints
- Trading
- Actual transmission
- Exchange of meter consumption data and settlement calculation
- Billing and settlement

These processes will rely on effective and efficient information exchange infrastructure. We therefore set the following requirements for the INFOXNET considering the fact that the electricity market is still evolving:

- The information infrastructure must be flexible enough to support all kinds of content sources, format, protocols, business rules, and the existing IT infrastructures.
- The system must support all market actors including big, medium and small actors.
- The system must be extensible. For example, the integration of the information systems for the control and co-ordination of distributed energy supply units such as renewable energy units like wind power must be possible.
- The electricity organisations must be able to discover and implement electronic interfaces to inter-operate in a secure, reliable and consistent manner.
- The INFOXNET must support the exchange of various types of data defined in the market rules, grid and distribution codes, such as nominations, transmission schedules, injection schedules, interchange schedules, meter consumption data, accounting information, etc.

We developed a use case model for the INFOXNET based on the system requirements. The main actors in the system are the regulator (NERC), TCN, Discos, Gencos, System and Market operators. The use case model for the requirements is depicted in figure 5.

The main use cases are Submit Nominations, Prepare Schedule, Submit Schedule, Aggregate Meter Data, Send Meter Data and Calculate Imbalance Quantity use cases. Due to space restriction, we will only describe two of the use cases to illustrate the role of use case model in the INFOXNET model development.

Send Meter Data: The Disco first aggregates the meter data per Genco before sending the meter data to the Market Operator in readiness for the calculation of imbalance energy quantities.

Calculate Imbalance Quantity: The Market Operator uses the transmission schedule and the meter consumption data per Genco received from the Discos, and the nominations from the Gencos to calculate the imbalance quantity for each Genco/IPP.

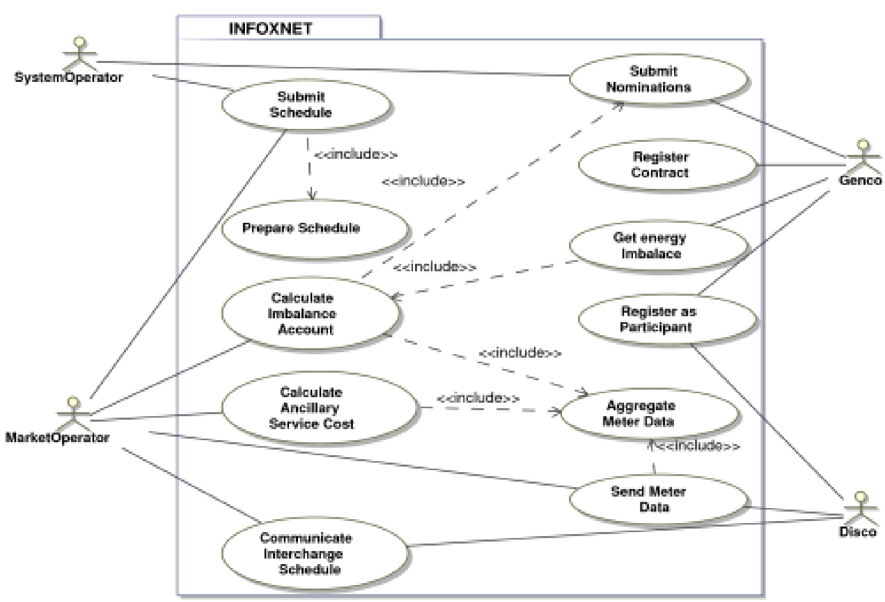


Figure 5: Use case model of INFOXNET. It shows how different organisations will use the INFOXNET to send and receive information

4.2 NFOXNET Object Model

We identified the relevant object classes from the application domain and the use case model - the entities of the data models. Entities such as *meter*, *connection point*, *Genco*, *Disco*, *market operator*, *system operator*, *energy consumer*, *Line* and *power station* etc. are considered. After the identification of the object classes, we identified the associations. The organisation of classes in a way that properties and structures are commonly used is an important aspect for the definition of object model. Through generalisation and specialisation, the identified classes can be organized so that the inheritance advantage of object-oriented can be used [16]. We use this concept to develop the object model of the INFOXNET representing the Nigeria deregulated electricity market described in section 3 earlier. The INFOXNET object model is organized into three sub-models: Market, Network and Common Data object models. We use three abstract classes (*MarketComponent*, *NetworkComponent and CommonDataComponent*) as subclasses of *INFOXNETBase* class to hierarchically organized the sub-model classes as shown in figure 6.

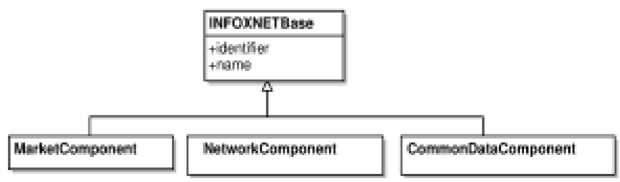


Figure 6: INFOXNET top-level object abstract classes

4.2.1 Market Component Model

The market component model (MCM) defines the organisations such as Disco, Genco, Market and System Operators etc. that will be involved in electricity market operations, the customers being served by these organisations and the market model adopted for the electricity market trading. The object model is shown in figure 7.

4.2.2 Network Component Model

Network component model (NCM) is concerned with the physical system that represents the physical aspects for network calculations and the requirements concerning a secure and reliable system operation under unstable market decisions. We used the approach adopted in [2, 16] to classify the network elements according to the number of terminal points to allow easy reproduction of the network topology connections. Topology information is stored as links between objects derived from class 2-pole (2-terminal object) and objects of class 1-pole (1-terminal object) as depicted in the association between 1-pole and 2-pole classes [2]. The hierarchy structure of the network model is shown in figure 8. A node/branch model for network calculations can be set up from the potential network topology by implementing a topology processor to generate the actual topology based on the defined states of the switches.

4.2.3 Common Data Component Model

The common data component model (CDCM) (figure 9) defines the energy data generated or consumed due to the market operations using the power network defined in the NCM. This component is at the core of the information exchange between the different organisations defined in the MCM.

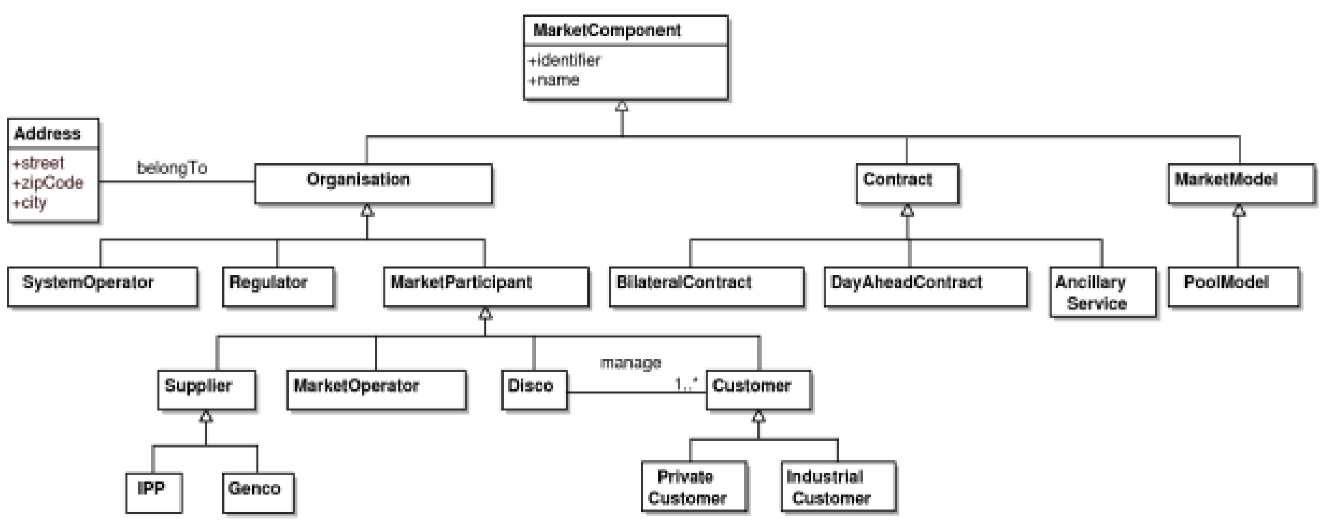


Figure 7: INFOXNET market component object model

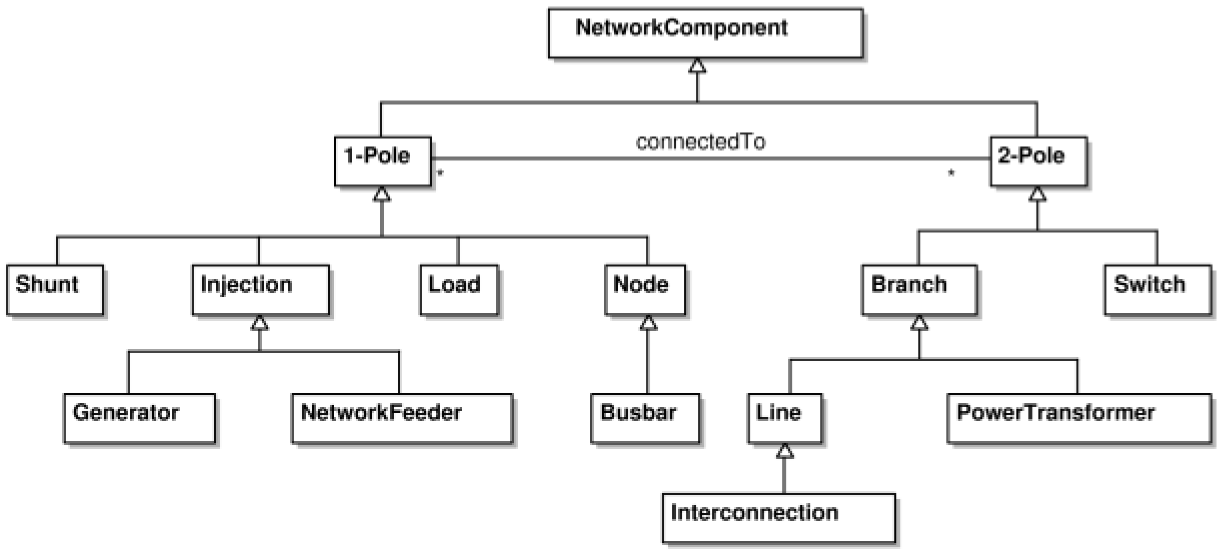


Figure 8: INFOXNET network component object model

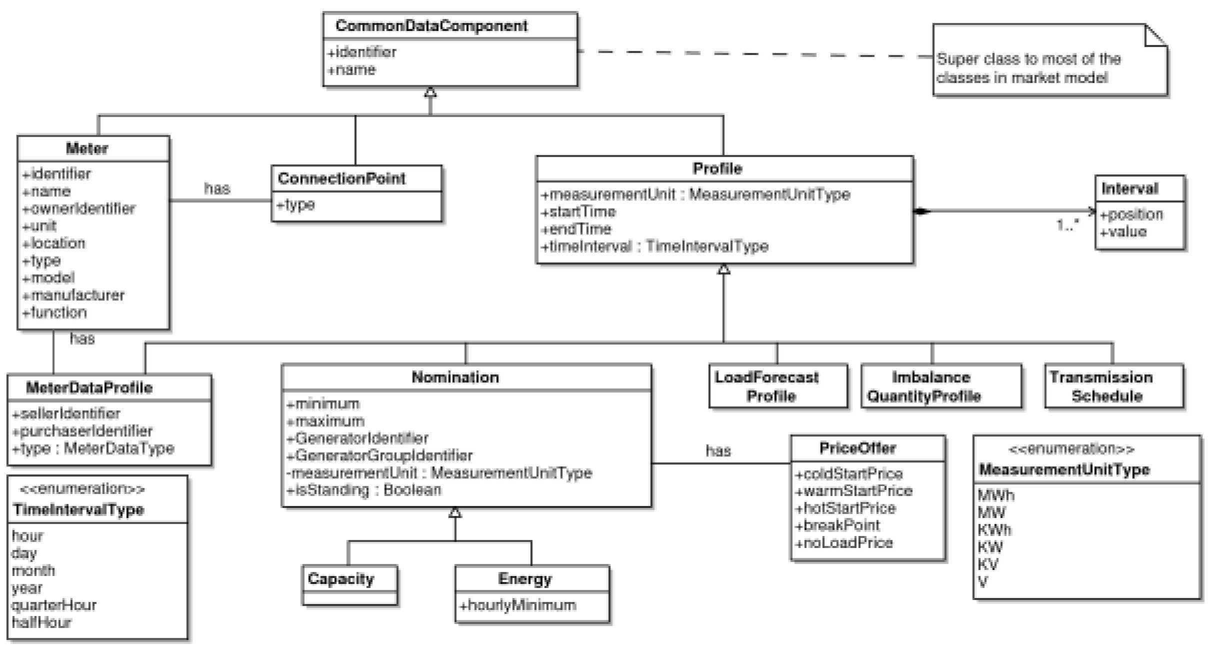


Figure 9: Fragment of INFOXNET common data component object model

4.2.4 Relationships between Component Objects

In deregulated electricity environment, market decisions affect power system operations and both market and network operations consume and generate data that are defined in the CDCM. Therefore, all the components defined above are interrelated through several classes of each component. A direct relationship between objects from different components occurs through references to objects, which are given as attributes of individual classes in the following forms:

- Supplier manage generators – objects of MCM and NCM
- Customer own load – objects of MCM and NCM
- Customer has connection point – objects of MCM and CDCM
- Disco manage meter – objects of MCM and CDCM
- Nomination has contract– object of CDCM and MCM

These references define information that is directly available to the different objects [22, 23]. This means, the Disco is, for example, responsible for the management of meters and associated meter data. In addition, there are also relationships between INFOXNET objects and the application tools that will be used for the management of power system and market operations. The integration of these application tools to the INFOXNNET model is explained in section 4.5.

4.3 INFOXNET Dynamic Model

Here we present the dynamic model of the INFOXNET using communication diagram. We developed communication diagrams corresponding to the earlier described use cases. These depict the objects defined in the object model, the use cases they participate in, and the messages passed among them. The combined communication diagrams for the use cases forms the overall communication diagram for the INFOXNET taking into consideration the concurrency in the system. Figure 10 shows a detailed communication diagram of *Send Meter Data* use case used as an example in section 2. The diagram depicts all the objects (from the object model) participating in the use case and the messages passed between. From the diagram, it is clear that the *Send Meter use case* cuts across business boundary. While the objects within an organisation are tightly coupled and can easily be managed, objects that cut across business boundary are loosely coupled and should be handled by means of communication messages using an appropriate technology as discussed in [16]. We therefore structured the INFOXNET model into subsystems to enable us analysis the messages between the loosely coupled electricity organisations using communication diagrams.

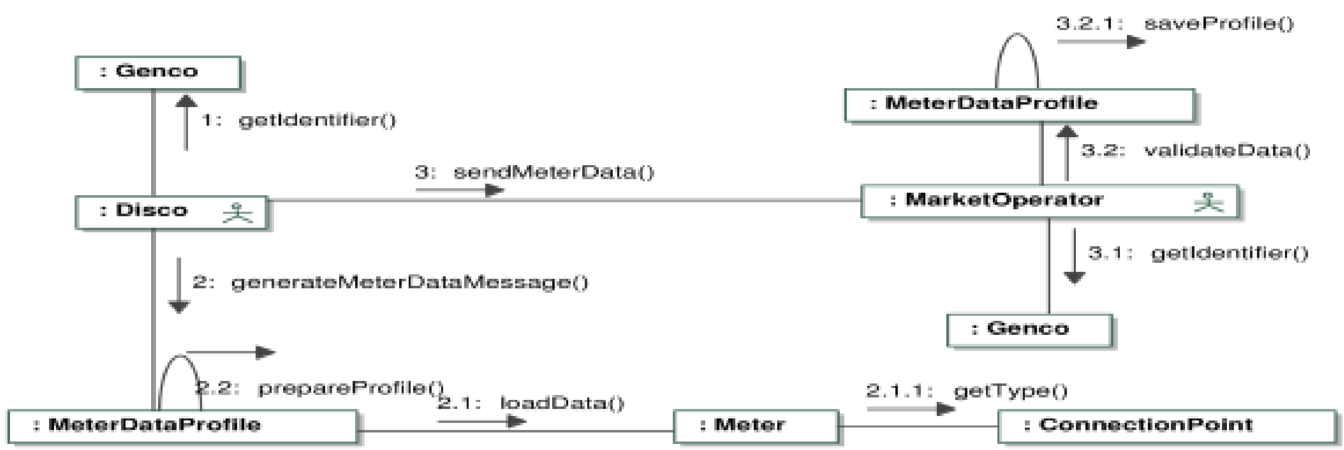


Figure 10: Communication diagram for send meter use case

4.3.1 INFOXNET Subsystems

The organisations operating the electricity market and power network are independent entities as earlier shown in the use case and object models, and the communication diagram. By considering the developed object model as a reference model, individual organisation will only need to deal with relevant object classes for fulfilling their respective functions. The fulfilment of the functions is dependent on the exchange of information as shown in the use case model. The information exchange is dependent on the electricity business processes by the market organisations. This type of information is referred to as Business Process Interaction Pattern Information (BPIPI) in [12]. Here we define it as Electricity Data eXchange (EDAX) model. In the current setting of the Nigeria deregulated electricity market, there is no requirement for frequent exchange of network component data between the organisations. Therefore, the EDAX model is basically the CDCM defined in section 4.2.2. EDAX will be at the core of the electricity trading in Nigeria deregulated electricity market. Aside from EDAX, the developed network reference model is structured into subsystems along the functions and roles of the organisations: Disco, Genco, TCN, System and Market Operator Network subsystems. EDAX contains the object model of the information to be exchanged between the main subsystems (i.e. the organisations) and forms the basis of data exchange in Nigeria electricity market.

A subsystem provides a larger-grained information hiding solution than an object. A subsystem class diagram shows the structural relationship between the subsystems. The main subsystems can further be structured into subsystems. For instance, each Information Network subsystem is structured into: Messaging Server (MS), Data Manager (DM) and Graphical User Interface (GUI) subsystems.

The dynamic interactions between the subsystems are usually shown on a high-level subsystem communication diagram [19]. An example of high-level subsystem communication diagram of the Disco and MO subsystems for *Send Meter Data use case* is shown in figure 11. The DM for respective INFOXNET main subsystems makes use of the objects involved in the *Send Meter Data* use case to produce or consume the meter data messages as shown in communication diagram earlier in figure 8. These objects must be kept separately by INFOXNET main subsystems. The identified subsystems are in agreement with the object-oriented basic concept of keeping objects with high coupling among each other in the same subsystem, and the weakly coupled objects in different subsystems.

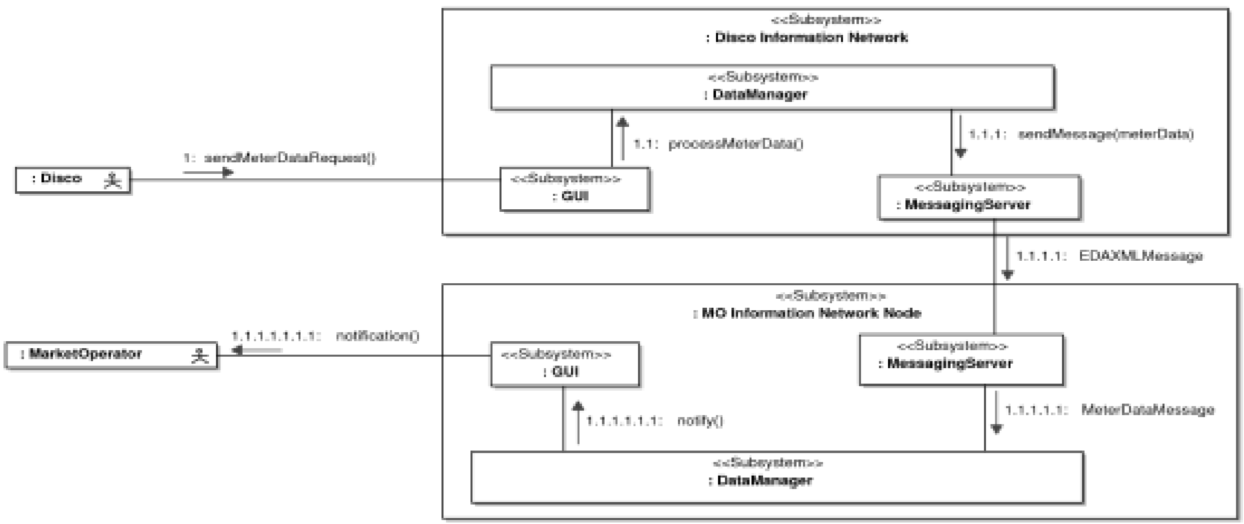


Figure 11: High-level communication diagram of Disco and MO subsystems for send meter data use case

4.4 Design of INFOXNET

We refined the object and dynamic models from the analysis phase described above. Using the dynamic model, we identified the operations of the classes for all the subsystems. The classes in the object model are updated using the operations obtained from both the communication diagrams. We propose relational databases for the management of data encapsulated by the entity classes for the INFOXNET subsystems. For accessing the data stored in the databases, database wrapper classes can be used [15]. Each entity class maintained at the INFOXNET subsystem is mapped to both relation (flat file) and a database wrapper class. A database wrapper class provides an object-oriented interface to the class and hides the details of how to access the data maintained in the relations. The attributes of object model entity class are mapped to a database relation, and the operations to access the attributes are mapped to a database wrapper class [24]. An example of database wrapper for *Meter* class is shown in figure 12. The main subsystems correspond to the network nodes of the INFOXNET. There is one node per an organisation. The basis of the information exchange between the organisations (INFOXNET nodes) as explained in [12] is the XML schema or Document Type Definition. The schema serves as a basis of communication between the organisations. All XML document received by an organisation is validated against the schema to check for the conformity of the document with the agreed information format. INFOXNET will encode this information in Electricity Data eXchange Markup Language (EDAXML). The EDAXML object model contains mainly object classes from the CDCM model defined in section 4.2.3. Figure 13 shows the fragment of the object model of the EDAXML showing only the newly introduced container class and some of the topmost class of the EDAXML model.

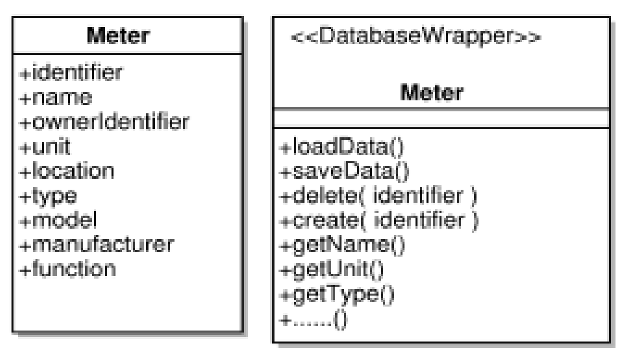


Figure 12: Example of database wrapper class (right: design model) that provides interface for accessing the data stored in the relational database for the Meter class (left: analysis model)

Each of the main subsystems (network nodes) as discussed above is sub-divided into MS, DM and GUI subsystems. Although these subsystems have the same name, their functionalities are dependent on the role and functions of the electricity organisations. We describe here briefly the subsystems.

- **MS subsystem** - responsible for the sending and receiving of XML document messages on behalf of the other subsystems. The subsystem sends and receives messages for the DM subsystem. It consists basically of the m*essage server*, m*essage producer* and the m*essage listener*. The MS subsystem uses the *message producer* to produce and send XML messages through the message server, while the *message server* uses the *message listener* to call the appropriate methods on the DM when message arrives. The subsystem is a configurable component. The instances are mapped to physical nodes (i.e. a node per organisation). The exchange of messages between nodes is according to the framework defined in [12].

- **DM subsystem** - manages the data within an organisation. It is responsible for the generation, sending and receiving of XML documents. EDAXML documents are generated from the database within the organisation using the database wrapper classes of the EDAX model. These are then sent to the concerned organisations through the MS subsystem. DM subsystem receives and processes the incoming XML messages through the MS subsystem into database using the database wrapper objects. The subsystem contains various database wrapper classes from the object model in section 4 and some other newly introduced classes. It provides point of integration to the application tools that will be deployed for the management and operation of the electricity market.

- **GUI subsystem** - provides user access to services provided by other subsystems. The GUI subsystem is a composite object composed of several simpler low-level user interface classes. The low-level user interface classes are widgets typically found in a user interface component library, such as windows, menus, buttons, and dialog boxes. The GUI is main interface to the organisations. It has operations for each of the windows displayed and for interaction with the MO. The GUI subsystem can be implemented in any programming languages such Java or C++ or web technology [16].

We obtained the operations for the classes of the subsystems for the design model of the INFOXNET nodes using the communication diagrams for the subsystems. The fragment of the design model of MO node is depicted in figure 14. The design models of other nodes (not shown here) are similar.

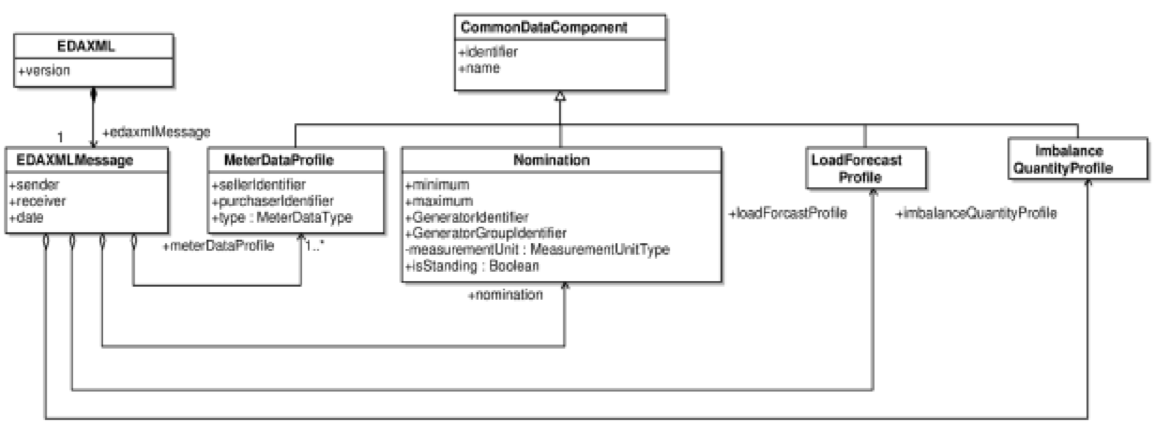


Figure 13: EDAXML object model

4.5 Implementation

The developed INFOXNET model is designed to be a reference model for deregulated Nigeria electricity market. Individual organisation will implement the network node depending on their roles and functions in the electricity market. By capturing the functionality of the INFOXNET using object-oriented conceptual modelling techniques, the development of the software components that constitute the solution space from the developed models (problem space) can easily be automated. For example, the implementation of the INFOXNET nodes can be semi-automated using appropriate tools and mappings between the conceptual models and software components. Individual organisation has freedom to choose any programming language of implementation since the reference model is independent of implementation language.

The EDAXML schema, which provides the basis of information exchange as earlier mentioned, is generated from EDAXML object model. Figure 15 shows the fragment of the EDAXML object model and EDAXML schema as well as an example of EDAXML document that will normally be exchanged between organisations.

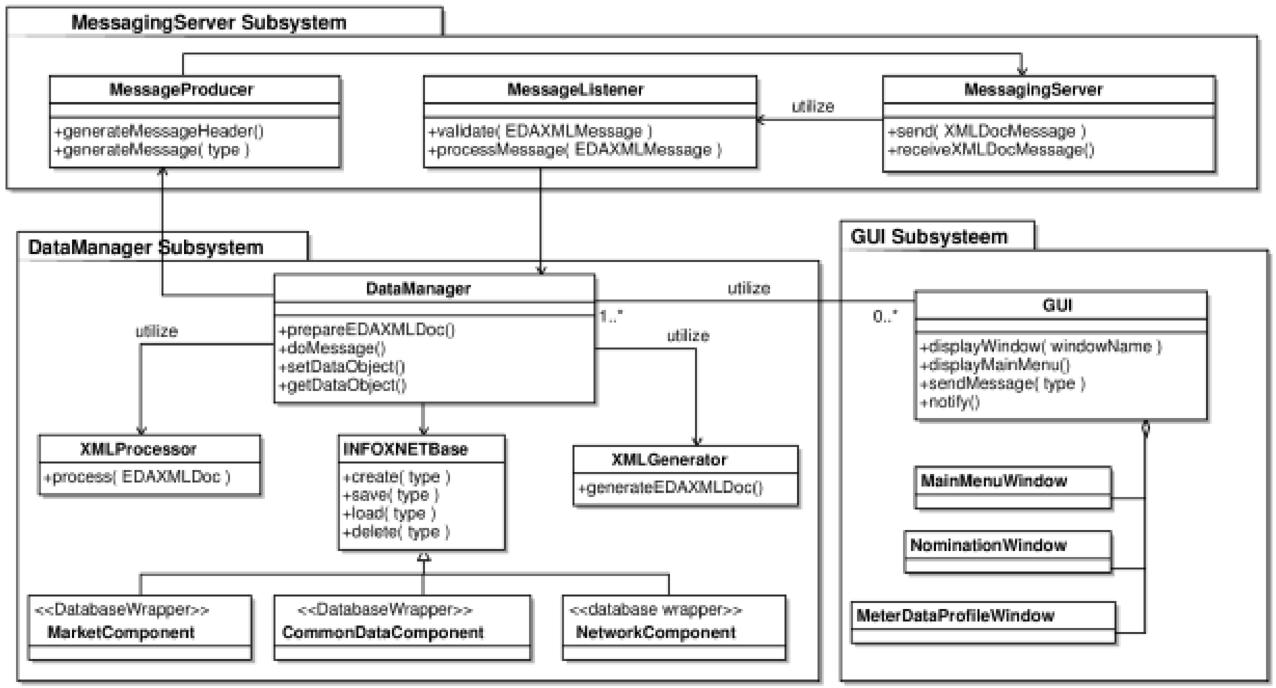


Figure 14: Fragment of the design model of INFOXNET node

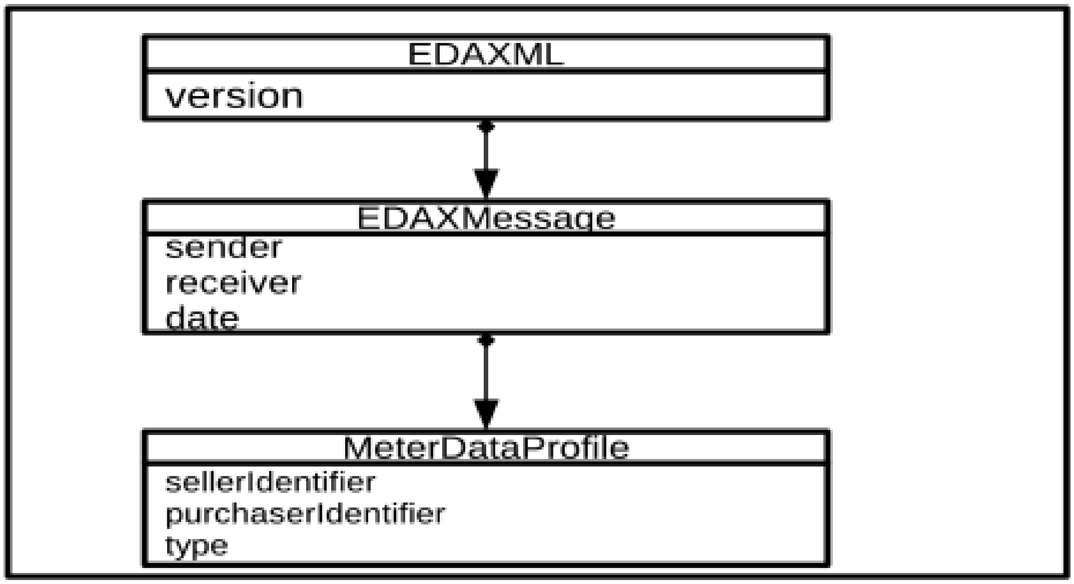
4.5.1 System Architecture

Clearly, the INFOXNET is a distributed system. The main subsystems or components developed are mapped to physical node for the organisations. There will be one autonomous node per each of the organisations. The overall architecture that shows the possible physical configuration of the system in terms of physical nodes and physical connections between the nodes, such as network connections, are usually specified in a deployment diagram [15]. The internal compositions of the nodes depend on the role and function of the organisations in the electricity market. However, the nodes exhibit certain common characteristics especially in the area of generation and sending of messages.

Information exchange between any two nodes is based on EDAXML document message format as defined in the information exchange framework developed in [12]. The role of an organisation in electricity market determines the type of EDAXML document message that the organisation will send to or receive from other organisations. The sending of a message from a communications partner to the other partner begins with the generation of EDAXML document that contains the actual data to be exchanged. The data can either come from the persistent layer through database wrapper or directly from application responsible for market management or network calculations. The receiving partner also stores the data into persistent layer through database wrapper. The use of database wrapper concepts for the data storage/retriever has been discussed earlier on. The persistent layer will contain the actual data as defined in the different INFOXNET components, while the database wrapper will provide the object-oriented interface to the relational database.

The primary users of the information exchange network model are the applications and tools that will be deployed for the management of network and market operations. The developed reference model is capable of supporting a diverse set of applications needed by the individual organisation for network and market operations. The reference model makes the integration of various applications quite convenient through the provision of appropriate application programming interface by the DM. Due to encapsulation, internal details of INFOXNET objects can be changed and new functionality can be added without affecting the existing application objects [2]. Figure 16 shows an example deployment diagram for the MO node with some applications accessing the instances of the INFOXNET object classes through the DM. Other nodes are similarly structured.

Object Model



EDAXML Schema

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema">
  <xsd:element name="profile">
    ....
  </xsd:element>
  <xsd:element name="meterDataProfile">
    ...
  </xsd:element>
  <xsd:element name="edaxmlMessage">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element ref="meterDataProfile" maxOccurs="unbounded"/>
      </xsd:sequence>
      <xsd:attribute name="sender" type="xsd:string" />
      <xsd:attribute name="receiver" type="xsd:string" />
      <xsd:attribute name="date" type="xsd:date" />
    </xsd:complexType>
  </xsd:element>
  <xsd:element name="edaxml">
    <xsd:complexType>
    <xsd:sequence>
      <xsd:element ref="edaxmlMessage" maxOccurs="1" />
    </xsd:sequence>
    </xsd:complexType>
  </xsd:element>
</xsd:schema>
```

EDAXML Document

```
<?xml version="1.0" encoding="UTF-8"?>
<edaxml xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <edaxmlMessage date="2013-01-20" sender="Disco1" receiver="MO1">
   <meterDataProfile identifier="239016" name="Trading Meter Data"
sellerIdentifier="Genco1" purchaserIdentifier="Disco1" type="energy">
  <profile startTime="" endTime="">
    <interval position="1" value="23.67" />
    <interval position="2" value="18.00" />
    <interval position="3" value="35.12" />
    <interval position="4" value="19.00" />
  </profile>
  </meterDataProfile>
 </edaxmlMessage>
</edaxml>
```

Figure 15: Fragment of EDAXML object model converted to schema and an example of EDAXML document based on the schema

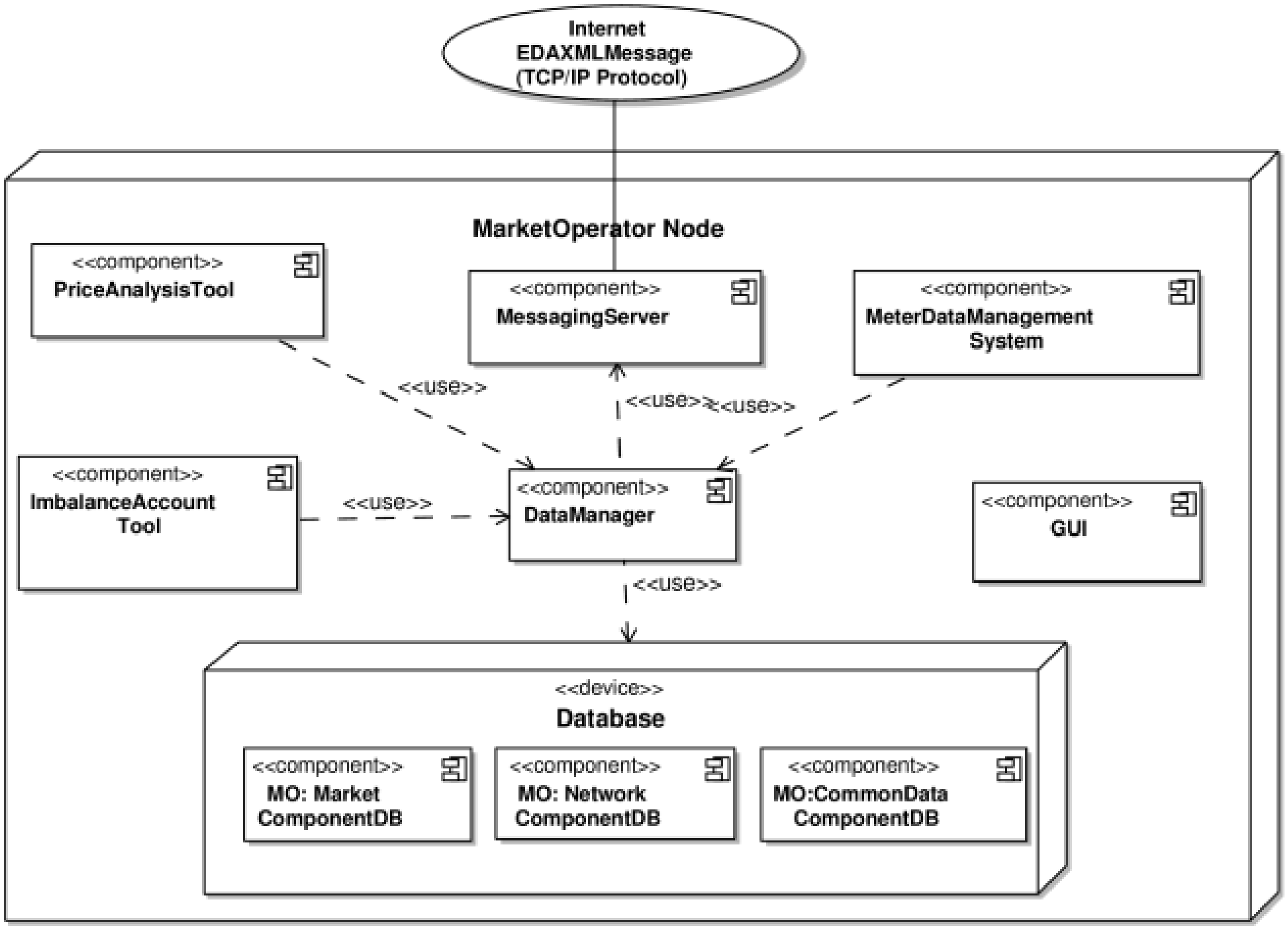


Figure 16: Deployment diagram of INFOXNET node for the MO

5. CONCLUSION

The emerging deregulated electricity market in Nigeria requires information exchange system that is capable of adjusting to the changes in the market environment. In this work, a reference model of the information exchange model referred to as INFOXNET has been developed for the deregulated market. We applied the object-oriented techniques to develop the INFOXNET model to enable the complex assemblies of participating organisations to exchange information and data with minimum human interactions. Automation of information exchange can only be possible with a suitable information model that is based on a method, which is technologically neutral. Object-oriented technology satisfies this requirement. It provides a unique approach not only for the implementation, but also for the analysis and design of the INFOXNET. Object-oriented analysis and design criteria enable the developed INFOXNET reference model to satisfy the requirements of flexibility, expandability, maintenance and data integrity by using encapsulation, polymorphism and inheritance.

All communication between the organisations is by means of messages. By converting the object model of the interaction patterns between the market actors into EDAXML schema for data representation medium for content exchange between the organisations as discussed in [12], the data exchange systems can support any content source and automate data extraction, delivery, and management. New organisations can easily be added by implementing the necessary network node. The proposed INFOXNET reference model is easily extensible and can be adjusted to different electricity market models.

The INFOXNET model combined with the framework presented in [12] will provide a very good starting point for the development and provision of a comprehensive information network infrastructures for effective take-up of deregulated electricity market in Nigeria. The schema obtained from the EDAXML model will enable the partners to exchange information using an agreed EDAXML schema, thereby ensuring improved data quality, and better integration across different sources, programmes and databases. It is only through the exchange of appropriate data and information that the reliability and security of electricity network can be guaranteed. Object-Oriented software engineering and XML technology enable the developed reference model to meet the requirements of flexibility and extensibility required for the rapidly evolving deregulated electricity market in Nigeria. We are currently working on Web Services based information system for the Market Operator using the developed INFOXNET reference model.

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