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Review Article

Service-oriented Data Mining Architecture for Climate-Smart Agriculture

Ajwang Stephen Oloo

Department of Informatics and Information Science, School of Information Communication and Media Studies, Rongo University, Rongo, Kenya

Email address:
oloohs@gmail.com, soloo@rongovarsity.ac.ke

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Abstract: The increasing volume of agricultural data and the availability of advanced technologies such as mobile platforms and connected devices have revolutionized the way data is captured, processed, stored and mined. The technologies have been applied in everyday life including agriculture, to enable creation of seamless systems that are intuitive and capable of providing real-time, affordable and accessible data to aid decision making. However, due to the inherent challenges of mobile platforms such as low-bandwidth networks, reduced storage space, limited battery power, slower processors and small screens to visualize the results, have hindered onboard data mining. Also, mobile devices have different platforms, which makes integration with server applications problematic. This paper, therefore, sought to solve these problems by proposing application of service-oriented architecture (SOA) based on web services, and artificial neural network (ANN) to facilitate mobile data mining of large agronomic and climate data, and prediction of yield and weather patterns. The architecture was proposed after a critical review of the available mobile data mining architecture. SOA was an ideal choice since it uses web services to improve inter-operability between clients and server applications independently from the different platforms they execute on hence providing data mining capabilities to mobile devices. The paper proposes a 7-layer architectural design premised on the concept advanced in the SO-M-Miner model. The components of the architecture included an SMS gateway, data client, mobile networks, web service, database and ODBC connector.

Keywords: Service-oriented Architecture, Data Mining, Climate-smart Agriculture, Artificial Neural Network, Web Services

1. Introductions

1.1. Service Oriented Architecture (SOA)

SOA has facilitated building of flexible, modular, and interoperable software applications [1]. It enables the composition of distributed applications regardless of their implementation details, deployment location, and initial objective of their development [2] due to the reuse capability within the applications and processes. A service-oriented architecture is based on the collection of services which when defined and deployed, operate independently of the state of any other service defined within the system.

SOA provides an application architecture where all functions are defined as independent services with well-defined interfaces, which can be called in sequences to form business processes [3]. This feature of SOA is a result of the availability of web services within the architecture creating an interoperable system comprising the roles of service providers, consumers and registry.

The increased use of SOA is due to its capability to be implemented over the internet using web services [4]. Web services incorporate standardized XML formalisms and internet protocols such as HTTP to permit the sharing of data independently from underlying platforms and programming languages over software and hardware infrastructures available for internet applications [5].

Web services differ in many aspects from the classical distributed architecture based on remote components such as RMI, CORBA and DCOM. For instance, web services use a platform-independent formalism for message exchange while classical architectures use low-level binary communications, thus data encoding completely depends on specific technologies.

Web Services in mobile environments

The market of mobile devices such as smartphones and PDAs is expanding very fast, with new technologies and functionalities appearing every day. Even if such devices share a common set of functionalities, they run on many different platforms, which makes integration with server applications problematic. However, web services can be exploited in mobile environments to improve interoperability between clients and server applications independently from the different platforms they execute on. The interoperability is achieved using:

Wireless Portal Network: has a gateway between the mobile client and the Web Service provider. The gateway receives the client requests and issue corresponding SOAP requests and return responses in a specific format supported by the mobile device [6].

Wireless Extended Internet: mobile clients interact directly with the Web Service provider whereby mobile clients become the true Web Services clients and can send or receive SOAP messages [6].

Peer-to-Peer (P2P) network: mobile devices can act both as Web Service clients and providers. This capability of acting both as consumer and provider is useful in systems such as ad hoc networks.

1.2. Review of Related Work on Service-Oriented Architectures

Adacal and Bener [7] proposed an architecture that includes the three standard web service roles of provider, consumer, and registry and three new components: a service broker, a workflow engine, and a mobile web service agent. The agent acts as a gateway to web services for mobile devices and manages all communication among mobile devices, service broker and the workflow engine. The agent, which is located inside the mobile network, receives the input parameters required for service execution from the mobile device and returns the executed service. It also selects services according to user preferences and context information such as location, air-link capacity, or access-network type. This architecture has limitations as it restricts data mining domains, applications, techniques and lacks proper workflow editing and management facility.

Chu et al. [8] proposed an architecture that divides the application components into two groups: local components, which are executed on the mobile device, and remote components, which are executed on the server-side. The system can dynamically reconfigure application components for local or remote execution to optimize a utility function derived from the user preferences. This approach implements a smart client model as opposed to *a* thin client implemented in wired scenarios. The architecture is not suitable for addressing integration challenges because it is only efficient in a wired environment and thus limit the number of users that can access the server at any given time.

Zahreddine and Mahmoud [9] proposed an approach for web service composition in which an agent performs the composition on behalf of the mobile user. In the architecture, the client request is sent to a server that creates an agent on behalf of the user. The request is then translated into a workflow to be performed by the agent. The agent looks for services that are published in a UDDI registry, retrieving the locations of multiple services that suit the request requirements. The agent then creates a specific workflow to follow, which entails the agent travelling from one platform to another completing the tasks in the workflow. This architecture does not support scalability and extensibility functionalities and thus limiting the number of client-server connections.

1.3. Web Service in Mobile Data Mining

Mobile data mining systems aim at providing “anytime, anywhere, anyplace” computing by decoupling users from devices and viewing applications as entities that perform tasks on behalf of users [10]. For example, Kagal et al [11] developed Centaurus which realizes the smart office scenario, where intelligent services are accessible to mobile users via hand-held devices connected over short-range wireless links. This connection is possible because mobile devices are equipped with wireless communication systems that enable a user to access global data services from any location [12].

Various studies have been conducted in mobile database system areas with the aim of enabling the devices to efficiently access many shared databases on stationary or mobile without having to be connected to a fixed physical link [13]. Despite these studies, mobile data mining is still limited by the typical challenges of a distributed data mining environment, with additional technological constraints such as low-bandwidth networks, reduced storage space, limited battery power, slower processors and small screens to visualize the results [14-15].

To solve the limitations of mobile devices, web services can be used to convert mobile devices to play the role of data producer, data analyzer, a client of remote data miners, or a combination of them. More specifically, we can envision three basic scenarios:

i. The mobile device is used as a terminal for ubiquitous access to a remote server that provides data mining services. In this scenario, the server analyzes data stored in a local or distributed database and sends the results of the data mining task to the mobile device for its visualization [16].
ii. Data generated in a mobile context are gathered through a mobile device and sent in a stream to a remote server to be stored into a local database. Data can be periodically analyzed by using specific data mining algorithms and the results used for making decisions [16].
iii. Mobile devices are used to perform data mining analysis. Even though this is limited by computing power and storage space of mobile devices. Therefore, it is not realistic to perform the whole data mining task on a small device. However, some steps of a data mining

task such as data selection and preprocessing can be run on small devices.

1.4. Existing Mobile Data Mining Architectures

Currently, there are various types of service-oriented mobile data mining architectures including MobiMine, VEDAS and SO-M-Miner.

MobiMine [13] is designed for intelligent monitoring of the stock market from mobile devices. MobiMine is based on the client-server architecture. The clients, running on mobile devices monitor a stream of financial data coming through a server. The server collects the stock market data from different web sources in a database and processes it on a regular basis using data mining techniques.

The clients query the database for the latest information about quotes and other information. A proxy is used for communication among clients and the database. Thus, when a user queries the database, the query is sent to the proxy which connects to the database, retrieves the results and sends them to the client. To efficiently communicate data mining models over wireless links with limited bandwidth, MobiMine uses a Fourier-based approach to represent the decision trees, which saves both memory on a mobile device and network bandwidth.

Another application of mobile data mining is the VEhicle DAta Stream mining (VEDAS) system [17] which monitors and mine vehicle data in real-time. The system is designed to monitor vehicles using onboard PDA-based systems connected through wireless networks. VEDAS continuously analyzes the data generated by the sensors located on most modern vehicles, identifies the emerging patterns, and reports them to a remote-control center over a low-bandwidth wireless network connection. VEDAS supports drivers by characterizing their status and helping fleet managers by quickly detecting security threats and vehicle problems.

Service-Oriented Mobile Data Mining model (SO-M-Miner) advanced by Derya [18] is another existing mobile data mining architecture. This model is widely exploited in modern scientific and business-oriented scenarios to implement distributed systems/algorithms using web services in which applications and components interact with each other independently from platforms and languages. They provide integration of computational services that can communicate and coordinate with each other to perform goal-directed tasks. This model is cost effective, increases the performance, throughput, flexibility and reliability of the server due to its distributed algorithm. The server can thus execute instructions and give quick responses to the varied information needs of users.

1.5. Choosing Mobile Data Mining Architecture

The cost of fixing an error found during requirements or early design phases is less costly to correct as compared to the same error found during testing. Architecture is the product of the early design phase, and its effect on the system and the project is profound. An unsuitable architecture will precipitate disaster on a project. For instance, performance goals will not be met; security goals will fall by the wayside [19]; the users will grow impatient because the right functionality is not available, and the system is too hard to change; and schedules and budgets required to rectify the problems will be immense [20].

It is, therefore, necessary to choose an appropriate architecture that will be ideal for mobile data mining. The architecture will determine the structure of the project including configuration control libraries, schedules and budgets, performance goals, team structure, documentation organization, testing and maintenance activities.

1.6. Climate-Smart Agriculture

According to FAO [21], climate change impedes the realization of global food security, eradication of poverty and achievement of Sustainable Development Goals (SDGs). Most farmers in developing countries are not adequately informed through sustained provision of information on how to cope with the menace of climate change.

In Kenya, agriculture is the mainstay of the economy, contributing about 25.9% of the GDP with 80% of Kenyans depending directly or indirectly on agriculture for their livelihoods [22]. The farming practices are mainly manual and rainfed at 75% of farms [22]. The rainfed agriculture faces the challenge of climate change compounded by lack of timely and relevant agricultural information reaching the smallholder farmers in poor rural communities. According to CIAT [23], mining large amounts of data can help optimize production and make agriculture more resilient to climate change. This deduction by CIAT formed the basis for the proposed service-oriented data mining architecture for climate-smart agriculture.

2. Material and Methods

As discussed in section 1.4, Mobi-Mine architecture can be used to implement data mining in stock exchange while VEDAS is applicable in the transportation industry. SO-M-Miner is applicable in modern scientific and business-oriented scenarios but can also be a suitable architecture for mobile mining of agricultural data since it implements the use of web service to enhance system efficiency and integrity. This paper, therefore, proposes an architecture based on the concept of SO-M-Miner to design a mobile data mining system to enhance data use in climate-smart agriculture.

The architectural design would lead to the development of a system that is capable of capturing, storing, mining and providing appropriate climate-based information through data analytics and data mining to enable farmers to cope with climate change in order to maximize agricultural productivity hence improved livelihoods. The system will require a data client, mobile networks, SMS gateway, web service, database and ODBC connector. The proposed design is discussed in section 3.

3. Proposed Architectural Design

3.1. Abstract View of the Proposed Architecture Figure 1

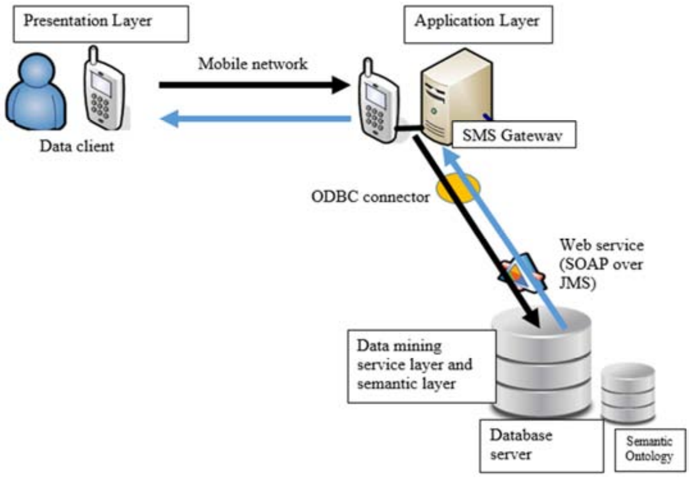

Figure 1. *Abstract view of the proposed architecture [24].*

The system will consist of a presentation layer (data client), application layer (SMS gateway- Ozeki SMS gateway), data mining layer (MySQL) and semantic layer (semantic ontology). The mobile user connects to the SMS gateway through a mobile network service provider such as Safaricom, Airtel or Telkom. The SMS gateway is connected to the MySQL database and semantic ontology through the ODBC connector over mobile web service (SOAP) to create SOA.

3.2. Layered View of the Proposed Architectural Design

This paper proposes seven-layer architecture shown in Figure 2 and discussed below:

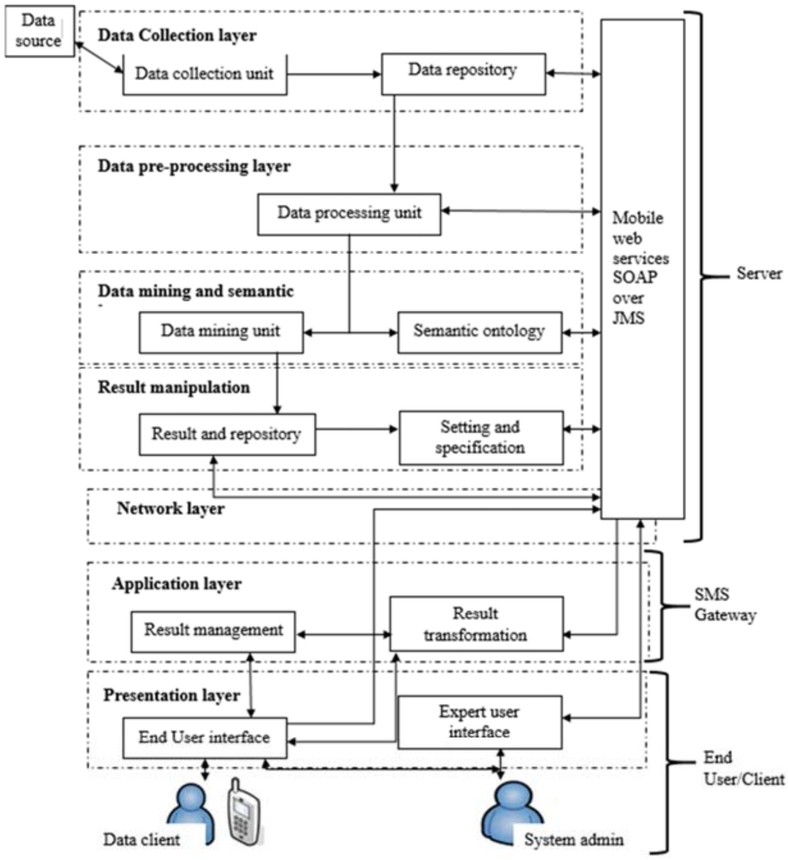

Figure 2. *Layered view of the proposed architecture. [24].*

Layer 1: Data Collection Layer design

This design is aimed at making data entry easy, logical and free of errors so as to enhance data consistency and integrity. The data collection layer design included the design of data entry controls

Data Entry Controls

These controls guide users on data entry so as to ensure that the data entered is correct and accurate by following the right procedure so as to avoid errors e.g. the right format to enter names of farmers, crop yields, harvesting dates, keywords, precipitation, planting dates, cultivar among others. The sources of data are:

a) Source document: information from farmers, extensions officers, metrological department, research institutions, government and private organizations among others.

b) Direct data entry: SMS received and sent are directly captured in the system database. User subscription details are also directly registered into various groups in the system.

Layer 2: Data pre-processing Layer design

i) Data model

The proposed architecture will use DFDs, Context diagrams and ER diagrams to design various processes of mining climate-smart agricultural information as shown herein:

a) Context diagram

In the proposed architecture, the system's external interactions are modelled in terms of data flows across the system boundary. The context diagram in Figure 3 shows the entire system as a single process.

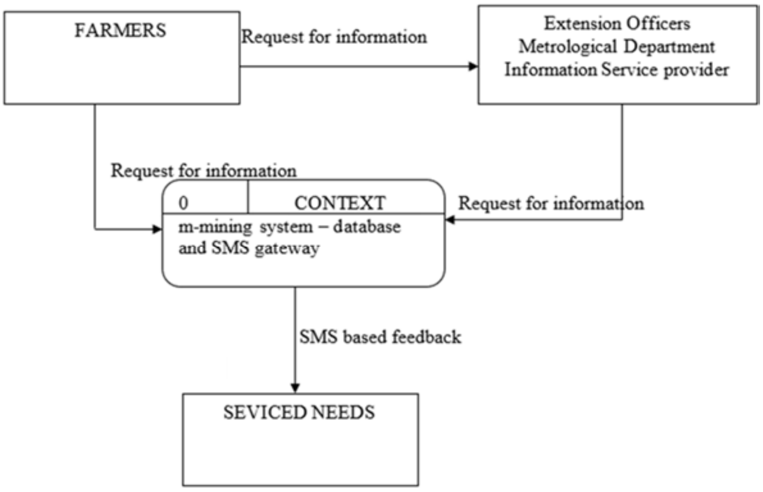

Figure 3. *Context diagram of the proposed architecture [24].*

b) Level 1 DFD

The Level 1 DFD shows how the system is divided into sub-systems (processes), each of which deals with one or more of the dataflows to or from an external agent, and which together provide all the functionality of the system. It also identifies internal data stores that must be present for the system to execute and shows the flow of data between the various layers of the architecture.

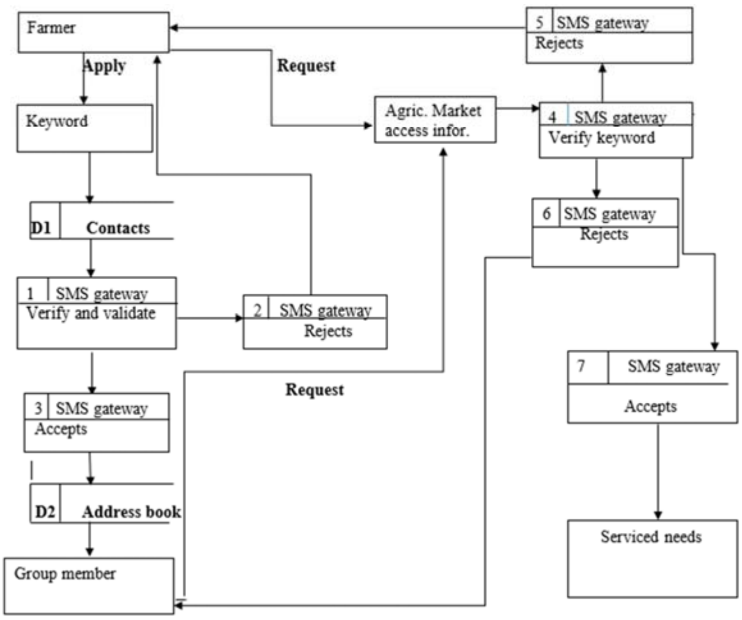

Figure 4. *Data flow Diagram (level 1 DFD) of the proposed architecture [24].*

Figure 4 represents two processes whereby a farmer either joins a group or request for climatic information. The data flow is represented by arrows signaling requests and applications for information. The internal data stores include the address book and contact group. The external agent includes the farmers, weathermen and extension officers. The keywords are verified, validated, accepted or rejected in each process.

ii) Database design

a) Relational schema

Some of the entities and the attributes to be used include:

Incoming messages (sender, receiver, message, sent time, received time, message type, and operator)

Outgoing messages (ID, sender, receiver, message, sent time, received time, message type, operator, reference, status)

Climatic information (keyword, temperature, precipitation, relative humidity and solar radiation)

Agronomic data (crop yield, grain humidity, sowing and harvest dates, cultivar, municipality and cropping system)

Membership (contactID, groupID)

Contact Group (ID, name, user_account, subscribe_keyword, greeting_message, unsubscribe keyword, bye message, allow subscription)

b) Entity modeling

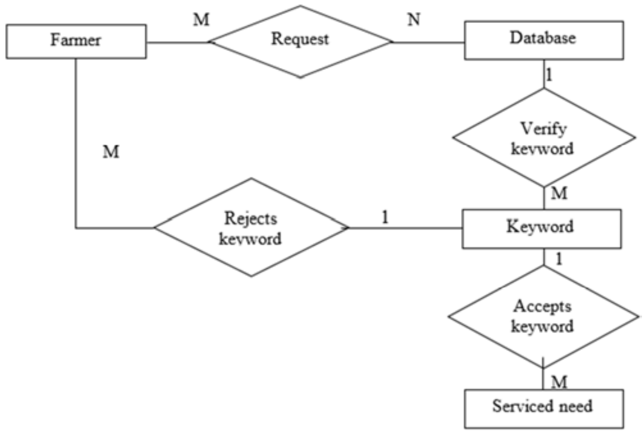

Figure 5. *Entity-relationship diagram for the proposed architecture [24].*

In Figure 5 above, a farmer sends a request to the database through the application layer using a keyword. The keyword is verified against the keywords and specification contained in the semantic ontology. If the keyword matches, it is accepted, and the need is serviced in form of SMS autoreply. If the keyword is rejected, an error message is sent back to the user.

c) Data dictionary

The description of data which will constitute the database for the system is discussed Table 1 below.

Table 1. *Data dictionary [24].*

Entity	Attribute	Data Type	Size	Description
Climatic_Information	Keyword	varchar	20	Uniquely identify the climatic information semantic
	Temperature	varchar	20	Degree Celsius
	Precipitation	varchar	160	Level of precipitation
	Humidity	varchar	160	Relative humidity
	Solar_radiation	varchar	160	Intensitiy of the radiation
Agronomic_Information	Keyword	varchar	20	Uniquely identify the agronomic information semantic
	Crop_yield	varchar	20	Tonnage per acre
	Sowing_date	Date stamp	30	Date of planting
	Harvesting_date	Date stamp	30	Date of harvesting
	Cultivar	varchar	160	Crop variety
	Sub_County	varchar	160	Locality of the farmer
	Cropping_system	varchar	160	Type of cropping system used
ozekismsin	ID	int	11	Uniquely identify the sender
	Sender	varchar	30	Sender of the message
	Receiver	varchar	30	Receiver of the message
	Msg	varchar	160	Message being received
	Senttime	varchar	100	Time that the message was sent
	Receivedtime	varchar	100	Time that the message was received
	Msgtype	varchar	20	Type of message
	operator	varchar	100	Mobile number operator
osekismsout	ID	int	11	Uniquely identifies the receiver
	Sender	varchar	30	Sender of the message
	Receiver	varchar	30	Recipient of the message
	Msg	varchar	160	Message being sent
	senttime	varchar	100	The time it was sent
	Receivedtime	varchar	100	Time the message was received
	Msgtype	varchar	20	Type of message
	Operator	varchar	100	Mobile service provider
	Reference	varchar	10	Message reference
	status	varchar	20	Status of the message

Entity	Attribute	Data Type	Size	Description
contactgroup	ID	int	20	Uniquely identify the group
	Name	varchar	160	Name of the group
	Useraccount	varchar	160	Account type
	subscribekeyword	varchar	160	The word for subscription
	Greetingmsg	varchar	160	Message for allowing subscription
	unsubcribekword	varchar	160	The word for unsubscribing
	Byemessage	varchar	160	Message for user who leaves a group
	allowsubscription	varchar	160	Accept request for subscription
membership	ContactID	int	20	Uniquely identifies the user
	GroupID	Int	20	Uniquely identifies the group

Layer 3: Data Mining and Semantic Layer

i) Data mining

The process of mining climate-smart agricultural information will involve connecting the system with the databases of Kenya Agricultural Livestock Research Organization to collect data on variables such as crop yield, grain humidity, sowing and harvest dates, cultivar, municipality and cropping system; and the database of Kenya Metrological Department which will provide daily records of five variables: maximum and minimum temperature, precipitation, relative humidity and solar radiation. Thereafter, the data will be selected and transformed into useful patterns/information through feed-forward computation as shown in figure 6 below:

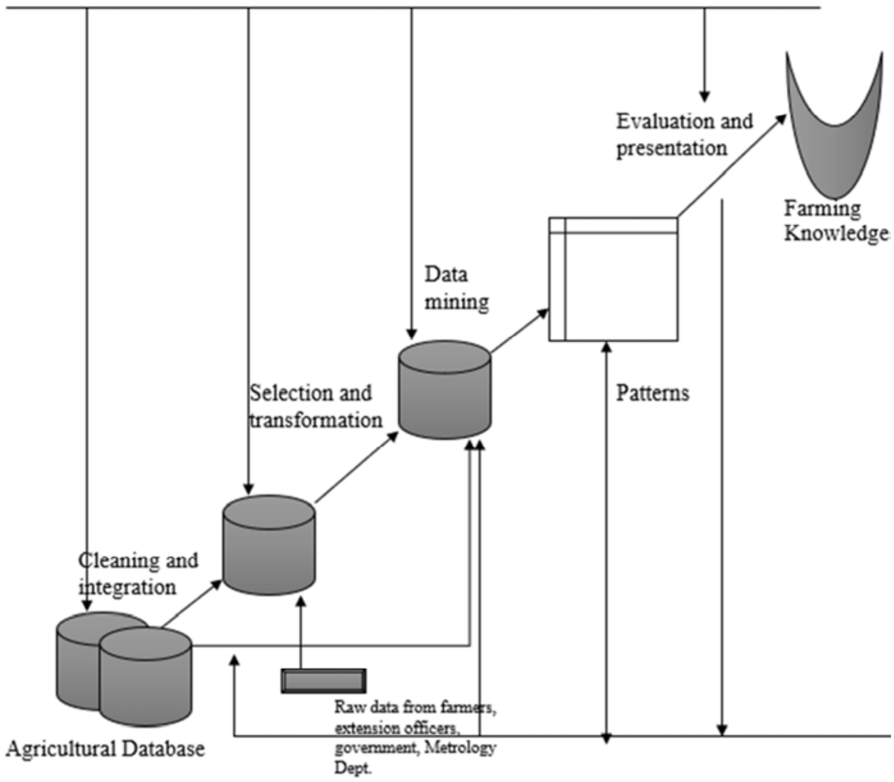

Figure 6. *Structure of m-mining database server [24].*

As a result of the slow processing power of mobile phones, the data mining task will be carried out at the back end (server) while the mobile device will be the client as per scenario one discussed by Devika et al [16].

Using prediction techniques provided by Artificial Neural Networks (ANN) to reveal the combination of recorded climatic factors and agronomic information that result in high or low yields in a specific region in Kenya, farmers will be able to forecast [25] the weather and yields and make necessary amendments to the farms. Figure 7 shows how ANN will be applied to support predictions.

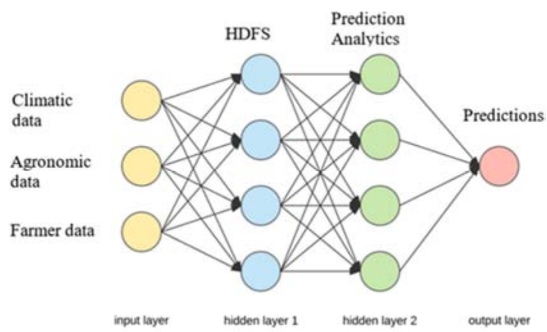

Figure 7. *Neural network architecture.*

If there is a change in any one of the recorded parameters like wind speed, wind direction, temperature, rainfall, humidity, then the upcoming climatic condition will be predicted using backpropagation algorithm. The algorithm is ideal for teaching ANN to perform certain mining tasks based on queries from users and changes in climatic conditions. It does this through supervised learning, implying that the service provider creates an algorithm with examples of the inputs and outputs wanted, the network to compute, and then the error is calculated progressively until the ANN learns the training data.

ii) Semantic Ontology

Ontology will support information exchange between the client and the server. In the proposed architecture, ontology will find the best match within the database server through SMS trigger and sends auto-reply i.e.

i. the keyword “JOIN” subscribes users into a membership group;
ii. the keyword “FORECAST” autoreply the weather forecast for the next 5 days
iii. the keyword “UNSUBSCRIBE” deregisters users from a group
iv. send error message when a wrong keyword is received by the system

Layer 4: Results Manipulation Layer

This layer ensures that the results of the data mining tasks are stored in the text files that can be accessed by a service provider. The logs containing users’ interaction/queries to the application and server will also be stored and updated in real-time. These files will be monitored and analyzed by a service provider to assess the access patterns of the users with a view to improving the users' experience. This layer will also store the results of the mining task for re-use arising from similar queries.

Layer 5: Network Layer

The network layer offers the necessary support for transport interconnections. It integrates and deploys a dynamic workbench for mobile networks, mobile web services and ODBC. The users will be connected to the application through the available mobile network services e.g. Safaricom, Telkom and Airtel. The application layer communicates to the server through mobile web services implemented by SOAP over JMS. SOAP over JMS is ideal in the proposed architecture because it supports communication without relying on internet access, and allows integration of mobile platforms. Through encapsulation, the encoded data remain unrecognized over the communication channels.

Layer 6: Application Layer

This layer comprises the design of the SMS Gateway API and the logical design.

i) SMS Gateway

The proposed architecture will use Ozeki NG - SMS Gateway, which communicates directly (inbound and outbound SMS) with the SMSC of the service provider and the database server. Ozeki NG-SMS Gateway handles inbound and outbound SMS between users and the service provider which are stored in the database connected to the server

Ozeki NG - SMS Gateway is used to send and receive SMS messages using a database server with the help of SQL queries. This is possible because database servers allow sharing of database tables between two applications.

Users will send SMS messages from a database server which will be handled by ozekismsout table. An outgoing message is inserted into this Atable using an SQL INSERT command. Ozeki NG - SMS Gateway periodically check (poll) the ozekismsout table with an SQL SELECT command, and if it finds a new entry, it sends the SMS message accordingly.

The user will receive SMS messages in a similar way but using ozekismsin table. If an SMS message is received from a mobile phone, it is inserted by Ozeki NG SMS gateway into the ozekismsin table. An SQL SELECT is used to read this message.

ii) Logical Design

The application layer was well-structured to allow the implementation of future changes or enhancement to the architecture. This was in recognition of the fact that user’s needs evolve over time and are bound to change therefore system that meets the users’ needs today may be totally irrelevant a few years to come. The architecture will therfore be adjusted in order to continue being relevant.

Layer 7: Presentation/User interface Layer design

The interface between the system and the user will be provided by a mobile phone platform and aided by the SMS feature available in all mobile phones. Due to low literacy levels characterized by most users, the SMS technology is an ideal interface between the user and the service provider. This is because SMS services are very simple to interact with and do not require additional training. This layer also involved the design of access control which ensured that certain information is only accessed by relevant and authorized users e.g. a user must log in as an administrator to access the content of the SMS gateway and the servers. A user must also register as a group member to access shared information with other farmers through SMS services. See Figure 8.

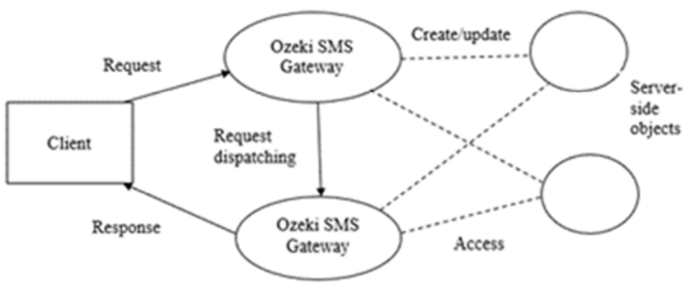

Figure 8. *Presentation Layer [24].*

3.3. Flow Charts for the Proposed Architecture

a) Requesting climatic information and auto-reply service through SMS. See Figure 9.

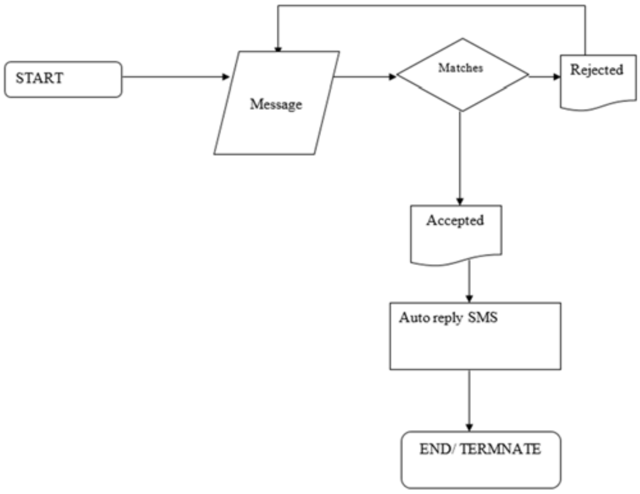

Figure 9. *Flow chart for requesting climatic information [24].*

According to the proposed architecture, a farmer will send an SMS comprising of a keyword. The keyword will be compared with the available keywords using the semantic web ontology. If the keyword matches, it will be accepted, and an autoreply triggered based on the keyword. Thereafter, the session will terminate. If the keyword does not match, it will be rejected, and a rejection message sent to the user. Thereafter, the session will terminate.

b) Flow chart for sending mined information to user/farmer groups. See Figure 10.

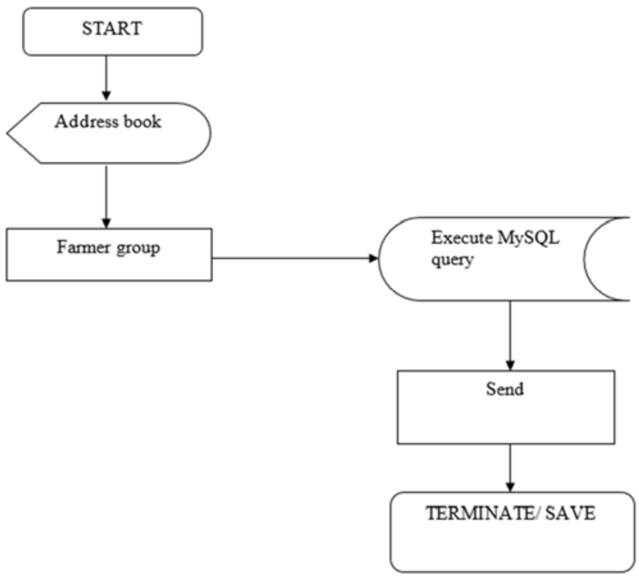

Figure 10. *Flow chart for sending mined information to farmer groups [24].*

The information service provider can also mine and send/share/disseminate information to various user groups. The process is represented as shown in b) above. Whereby, the information service provider or administrator searches through the address book for the appropriate user group, then executes MySQL query to send the results to the identified user group.

4. Conclusion

The integration of web services in data mining architecture can revolutionize how the available big data, interconnected devices and integrated agricultural systems can be enhanced to provide relevant and timely climate-smart agricultural information for improved crop productivity. This paper proposes mobile data mining architecture that applies the concept of SOA and use of big data analytics platforms such as ANN to discover patterns that can help to predict the relationship between the prevailing weather conditions and the effect on crop yield. This will enable farmers to make appropriate agronomic decisions based on available data. With the advancement of the internet of things and the introduction of 5G network, it will be interesting to observe how these technologies can further be integrated into the proposed architecture.

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