Predictive Analytics with IoT: Research Trends, Methods, and Architectures Using Systematic Literature Review

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Abstract

Background - IoT research on intelligent service systems is currently trending. IoT generates various kinds of data from sensors or smartphones. The data generated from IoT can become more useful and actionable if data analysis is performed.

Objective - Predictive analytics with IoT is a part of data analysis that aims to predict a solution. The utilization of this analysis produces innovative applications in various fields with various predictive analytic methods or techniques.

Research Methodology - This research uses Systematic Literature Review (SLR) to understand the research trends, methods, and architectures used in predictive analytics with IoT. So the first step is to determine the research question (RQ) then search for some literature published in popular journal databases namely IEEE Xplore, Scopus and ACM from 2015 - 2023.

Findings - The results of the review of thirty (30) selected articles, there are several research fields that are trending, namely Transportation, Agriculture, Health, Industry, Smart Home, and Environment. The most researched field is agriculture. Predictive analytics with IoT uses methods that vary according to the data conditions used. There are five most widely used methods, namely Bayesian Network (BN), Artificial Neural Network (ANN), Recurrent Neural Network (RNN), Neural Network (NN), and Support Vector Machines (SVM). Some studies have also proposed architectures that use predictive analytics with IoT.

Managerial Implications - This research can help the government in designing policies and regulations that support the use of IoT technology in predictive analytics. This can help promote innovation in public services, such as disaster prediction and mitigation, environmental monitoring, and more efficient transportation management.

Keywords: Predictive Analytics, IoT, Systematic Literature Review, SLR.

1. Introduction

The development of technology and information brings great changes in all fields, especially the Internet of Things (IoT). With the IoT, the number of internet-connected devices ranging from sensors and smart phones has increased significantly. By 2020, the number of these devices is expected to increase to around 50 billion [1]. This increasing number of devices generates a diverse amount of data. The availability of data generated by these diverse devices has opened up new opportunities for innovative applications in various fields, such as intelligent transportation systems [2], intelligent healthcare [3], intelligent agricultural systems [4] and so on.

As is known, IoT collects a variety of data from sensors, smart phones or other internet-connected devices and stores them on servers or the cloud. The data can be continuous numbers from temperature sensors or images/video from cameras. To turn the data into more useful and actionable information or knowledge, the data must be analyzed using certain methods or techniques. This data analysis requires the use of artificial intelligence (AI), machine learning (ML), and predictive analytics techniques with the aim of sifting through the data, identifying trends and predicting appropriate solutions.

Predictive analytics with IoT is a subset of data analytics that aims to predict data based on patterns extracted from historical data derived from IoT data. Predictive analytics is what makes the system look smarter. Predictive analytics with IoT has been widely applied in various fields as part of intelligent service systems, such as traffic jam prediction from traffic, weather and social media data in intelligent transportation systems [2], heart attack prediction from temperature data and a person's heart rate in intelligent health systems [5], plant disease prediction from temperature, humidity and air content data in intelligent agricultural systems [4] and others.

IoT data is usually heterogeneous, fast-growing, large-volume, and requires real-time analysis. Traditional predictive analysis techniques alone are not sufficient to analyze the complex data generated by IoT [6]. There are various methods or techniques that can be used to analyze this data such as Artificial Neural Networks (ANN) [7], Bayesian Network (BN) [2], Support Vector Machines (SVM) [8] and other methods.

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To better understand predictive analytics with IoT, this research conducted a literature review using Systematic Literature Review (SLR). SLR can help find solutions by reviewing previous relevant research. The purpose of this study is to understand the research trends, methods, and architectures used in predictive analytics with IoT. To get comprehensive results, the research was conducted on several literatures published in popular journal databases such as IEEE Xplore, Scopus and ACM from 2015 - 2023.

This article consists of four sections. Section 2 provides an explanation of the systematic literature review as the methodology of this research. Section 3 describes the results of the review and answers to the research questions. Section 4 presents the research conclusions and suggestions for future work.

Contributions This research can assist the government in designing policies and regulations that support the use of IoT technology in predictive analytics. This can help promote innovation in public services, such as disaster prediction and mitigation, environmental monitoring, and more efficient transportation management.

2. Research Methodology

2.1 Systematic Literature Review

Systematic Literature Review (SLR) is a secondary study to map, identify, critically evaluate, consolidate, and collect the results of major studies on a particular research topic [9]. SLR is a standard method for getting answers by conducting a literature review based on previous related studies. The purpose of conducting SLR is to summarize previous research, to identify gaps that need to be filled between previous and current research, to produce a coherent report/synthesis, and to create a research framework.

The purpose of the literature study in this research is to understand the trending research topics, methods, and architectures on predictive analytics with IoT. To get comprehensive results, the research took some published literature from popular database journals namely IEEE Xplore, Scopus, and ACM from 2015 to 2023.

2.2 Research Question

The purpose of the Research Question is to maintain the focus of the literature review. This facilitates the process of finding the necessary data. Table 1 shows the research questions for this study.

Tabel 1 Research Question

ID	*Research Question*	Motiva si
RQ 1	What are the trending research topics in the field of Predictive Analytics with IoT?	Identification of trending research topics in the field of Predictive Analytics with IoT
RQ 2	What are the methods used in Predictive Analytics with IoT?	Identify the methods used in Predictive Analytics with IoT
RQ 3	What are the architectures in Predictive Analytics with IoT?	Architecture identification in Predictive Analytics with IoT

2.3 Search Results

To answer the Research Question described above, the research conducted a search on a popular journal database with specific keywords for the search. The keywords used are: predict* AND IoT AND (analyze* OR method OR technique OR architecture). The search with these keywords was carried out in the abstract section only. The search results found 674 articles. Table 2 shows the results of the search process using these keywords.

Table 2 Related Research Search Results

No	Journal Database	Number of Articles
1	IEEEXplore	475
2	Scopus	125
3	ACM	74
Tota l		674

Inclusion and exclusion criteria were used to select the primary research. The results of articles from these criteria will later be reviewed by researchers. The inclusion and exclusion criteria can be seen in table 3.

Table 3 Inclusion and Exclusion Criteria

Criteria Inclusion	I1	Articles related to trends, methods/techniques and architectures on predictive analytics with IoT
	I2	Articles written in English
	I3	Articles can be accessed in full
Criteria Exclusion	E1	Same article from different journal databases
	E2	Journal articles that are not indexed by Q1, Q2 and Q3
	E3	Unranked conference articles

After filtering with inclusion and exclusion criteria on the search result articles using keywords, several journal and conference articles were obtained as shown in Table 4. The number of articles obtained is 30 articles both journals and conferences. This article will be reviewed in this research.

Table 4 Filtering Process Results

No	Publikasi	JumlahArtikel
1	JurnalQ1	11
2	JurnalQ2	8
3	JurnalQ3	1
4	*Conference*	10
	Total	30

III. Research Results

3.1 Research Trends in Predictive Analytics with IoT

Based on the results of the literature review, there are six research fields that are trending in predictive analytics with IoT, namely Transportation, Agriculture, Health, Industry, Smart Home, and Environment. Currently, the most researched field is agriculture. Table 5 shows the trends of predictive analytics research fields with IoT and their references.

Table 5 Research Fields of Predictive Analytics with IoT

No	Field	Reference
1.	Agriculture	[4][7][14][15][16][17][18]
2.	Transportation	[2][6][10][11][12][13]
3.	Health	[3][5][19][20][21][22]
4.	Environment	[28][29][30][31]
5.	Smart Home	[1][25][26][27]
6.	Industry	[8][23][24]

Currently, agriculture is the most researched topic of predictive analytics with IoT. Applications of predictive analytics in this field include predicting extreme weather that will affect crops [14][16], predicting fish and plant growth [15], predicting plant diseases [4][18], monitoring plant growth [17], and predicting stress in dairy cows [7]. The application of predictive analytics with IoT has great potential in the agricultural sector. This is very helpful for farmers to increase the productivity of agricultural products.

In the field of transportation, the topics studied include traffic congestion prediction [2][6][10][11][12] and parking availability prediction [13]. As is known, big cities in the world have the main problem of traffic congestion. With the development of Intelligent Transportation System and IoT, which includes the prediction of traffic congestion in real time, this can be a solution to overcome the problem of congestion. One of the benefits is that transportation users can avoid roads that are congested so that it does not get worse.

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In the health field, topics researched include smart logs for monitoring children's food nutrition [19], early detection of diseases [3][20][21] and prediction of blood pressure reduction [22]. One of the benefits of predictive analytics with IoT in this field is real-time health monitoring for early detection of life-threatening diseases through advanced sensing and communication technologies so as to provide better treatment, reduce medical costs and save human lives.
Application in the environmental field is very helpful for the realization of environmental protection, for example, prediction of air or water quality [29], or atmospheric or soil conditions [30]. Not only that, predictive analysis with IoT can be utilized in disaster management such as early warning systems [28]. This is certainly very helpful for the safety of human life in disaster-prone areas.
Smart home that aims to improve the comfort of its residents is certainly a trending research topic. Applications of predictive analysis in this field include optimal energy utilization by operating equipment only when needed [25][26][27] and prediction of water usage [27]. One of the benefits gained is the reduction of electrical energy consumption as much as possible.
In the industrial field, predictive analytics with IoT is needed. Topics studied include asset management for asset maintenance prediction [8], worker safety accident prevention and predicting replacement cycles for motor management in the field of industrial robots [23]. The use of IoT in predicting asset maintenance is very useful for identifying potential problems before damage to the machine occurs.

3.2 Methods used in Predictive Analytics with IoT

The review found that there are twenty-three types of methods used in predictive analytics with IoT. The methods used are in the form of algorithms or models. The difference in methods is influenced by the condition of the data used, both predictor data and prediction data. Table 6 shows the list of methods used in predictive analysis with IoT.
Based on the twenty-three types of methods shown in table 6, there are five most widely used methods, namely Bayesian Network (BN), Artificial Neural Network (ANN), Recurrent Neural Networks (RNN), Neural Network (NN), and Support Vector Machines (SVM).

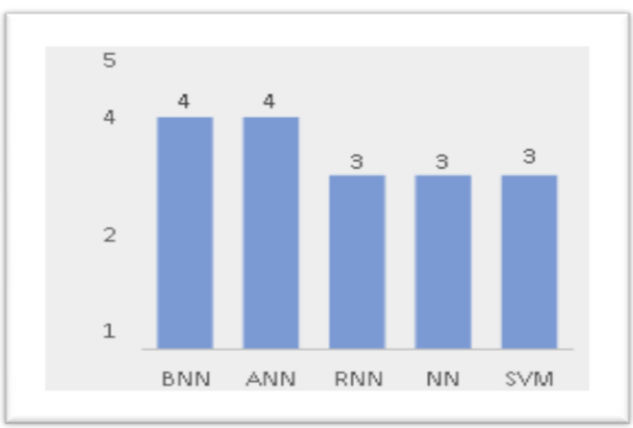

Figure 1 Most used methods

Several studies on predictive analytics with IoT reported performance comparisons of the methods used. Congestion prediction research on large-scale transportation networks compared four predictive methods namely RNN-RBM, BPNN, and SVM [10]. The results show that the method using RNN-RBM has the best accuracy rate compared to other methods. Parking availability prediction research compared three algorithm methods namely RT, NN and SVR [13]. The evaluation shows that RT is the least computationally intensive algorithm and the best prediction performance compared to the other two methods, namely NN and SVR. K-NN, Naïve Bayes, SVM and ANN are used to predict devices in smart homes that can be turned off [1]. The evaluation shows that the K-NN algorithm has the best prediction performance compared to the other three methods.

Table 6 Predictive Analytics Methods with IoT

No	Metode	Reference
1.	Adaptive Moving Window Regression (AMWR)	[6]
2.	Bayesian Network (BN)	[2][14][23][19]
3.	Random Forest (RF)	[14]
4.	Recurrent Activity Predictor (RAP)	[25]
5.	Holt‟s Linear Trend Method	[3]
6.	Hidden Markov Model	[26]
7.	Restricted Boltzmann Machine(RBM)	[10][8]
8.	Artificial Neural Network(ANN)	[31][29][1][7]
9	Robustness Analysis	[15]
10	General Infection Model	[4]
11	Recurrent Neural Networks (RNN)	[10][20][27]
12	Back Propagation Neural Network (BPNN)	[10]
13	Hybrid Prediction Model (HPM)	[21]
14	ARIMA	[16]
15	Neural Network (NN)	[16][13][8]
16	Decision Tree	[17][30]
17	Dynamic Bayesian Networks (DBN)	[11][12]
18	Multiple Regression	[22][8]
19	Regression Tree (RT)	[13]
20	Support Vector Regression (SVR)	[13]
21	K-Nearest Neighbor (KNN)	[1][24]
22	Naïve Bayes	[1]
23	Support Vector Machines (SVM)	[10][1][18][8]

Several researchers proposed improved methods from some of the methods that are usually used. In traffic jam prediction, an adaptive prediction method called AMWR is used [6]. The AMWR method is used for dynamic IoT data. This method consists of three main steps, namely the selection of regression algorithms, finding the optimum training window size, and prediction horizon size. The prediction accuracy rate generated by the AMWR method shows a better number.

3.3 Architecture for Predictive Analytics with IoT

Based on the literature review, there are four proposed architectures that use predictive analytics with IoT, namely Akbar et al Architecture [6], Abdulatif et al Architecture [3], Jo et al Architecture [29], and Patil et al Architecture [17].

3.3.1 Akbar et al Architecture

Akbar et al. proposed and implemented a generic architecture based on open source components to combine machine learning (ML) with complex event processing (CEP). The goal is to predict complex events in proactive IoT applications. This architecture uses both historical and real time data. Figure 2 shows the architecture proposed by Akbar et al. on intelligent transportation systems.

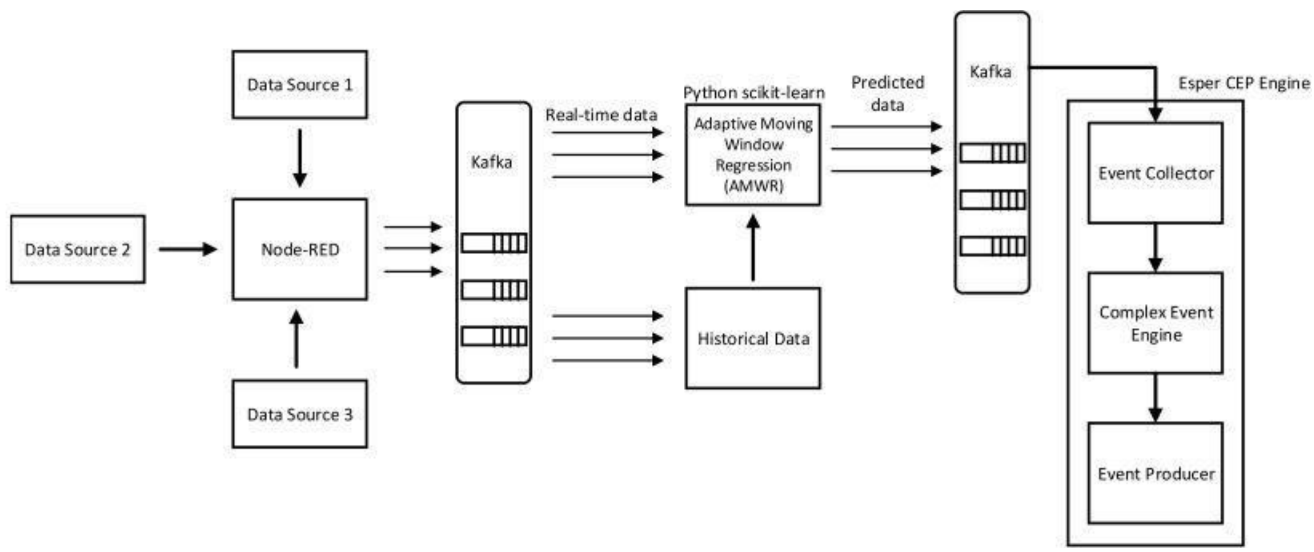

Figure 2 Akbar et al architecture - Image taken from [6]

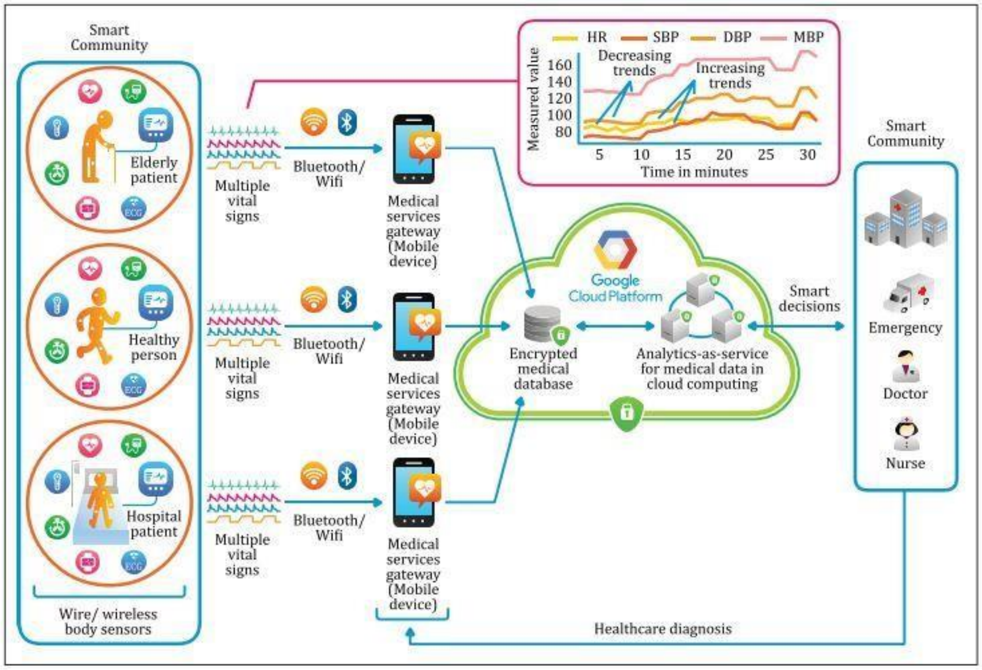

Figure 3 Architecture of Abdulatif et al - Image taken from [3].

Based on Figure 2, Node-RED serves as a front end where data from different sources is accessed then the data is preprocessed such as filtering redundant data and changing the required data format. Data preprocessing is done by Kafka. Real-time data and historical data are accessed from Kafka and then predictions are made using the AMWR model which presents the ML component. The AMWR model consists of three main steps: selecting the regression algorithm, finding the optimum training window size, and sizing the prediction horizon. Prediction data is entered in Kafka in the form of event tuples. Kafka is an open source tool to publish and subscribe data in real time.

3.3.2 Abdulatif et al architecture

Abdulatif et al's proposed architecture provides a cloud-based real-time change detection and abnormal prediction framework that maintains privacy for several patient vital signs. This architecture is used in intelligent health systems to predict or early detection of patient diseases. Abdulatif et al's architecture is shown in Figure 3.

The Abdulatif et al architecture has three main entities, which are as follows:

a) Smart Community Resident (SCR): Vital signs data on community residents can be collected and sent directly directly to cloud-based storage.
b) Cloud Storage (CS): Used to store SCR data in encrypted form.
c) Smart Prediction Model (SPM): The core entity of the system where the collected encrypted data is processed based on a mathematical model to detect abnormal changes in the SCR vital signs.

The three entities collaborate to monitor and predict the vital signs of each SCR. After the encrypted data is sent to the CS, the SPM works independently to analyze the encrypted data securely (without decrypting). The SCR can retrieve the encrypted results through the CS and can be securely decrypted only on the SCR side.

3.3.3 Jo et al Architecture

The Jo et al architecture is specifically designed for air quality monitoring and assessment systems in underground coal mines. This architecture proposes a main framework consisting of data acquisition, data transmission, data processing (for air quality assessment and prediction) and services for information sharing and intelligent control of mine ventilators. This architecture is shown in figure 4.

In this system, the sensing unit is based on a sensor module attached to an Arduino. Two sensing units form Sensor Nodes (SN), which capture air quality-related data and transmit this data to the base station via ZigBee. The base station runs Azure Machine Learning (AML), which operates as a platform as service (PaaS). The air quality model extracts pollutant types and predicts air quality based on pollutant concentrations. Thus, the system performs AML-based autonomous decision-making and control.

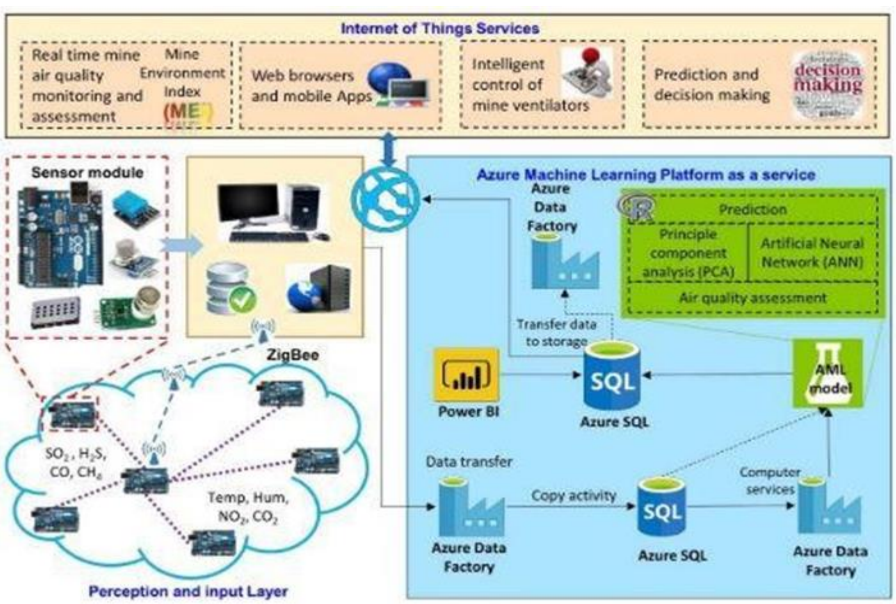

Figure 4 Jo et al architecture - Image taken from [29]

3.3.4 Patil et al architecture

The research proposed by Patil et al focuses on the effective use of IoT devices and efficient algorithms for sensing data improvement and prediction by decision learning. This system architecture is used in intelligent agricultural systems to predict plant growth and disease. In this system design, Patil et al. incorporated communication flows between system components and different inputs/outputs for modules in different systems. The architecture of Patil et al is shown in Figure 5.

The main components of the system consist of three things namely: IoT devices, data repair algorithms and machine learning algorithms for prediction. IoT devices are responsible for collecting data such as humidity, temperature, and plant conditions. IoT components, such as And Cube (IoT Gateway) and Mobius (IoT Service platform), are integrated in the proposed system to provide intelligent solutions for plant growth monitoring. The data improvement algorithm uses Kalman Filter (KF) to filter the data for quality data without noise before the data is used for prediction. The predictive analysis algorithm used for decision making is Decision tree. The prediction results in this system are crop yield prediction, plant classification, soil classification, weather prediction, and plant disease prediction.

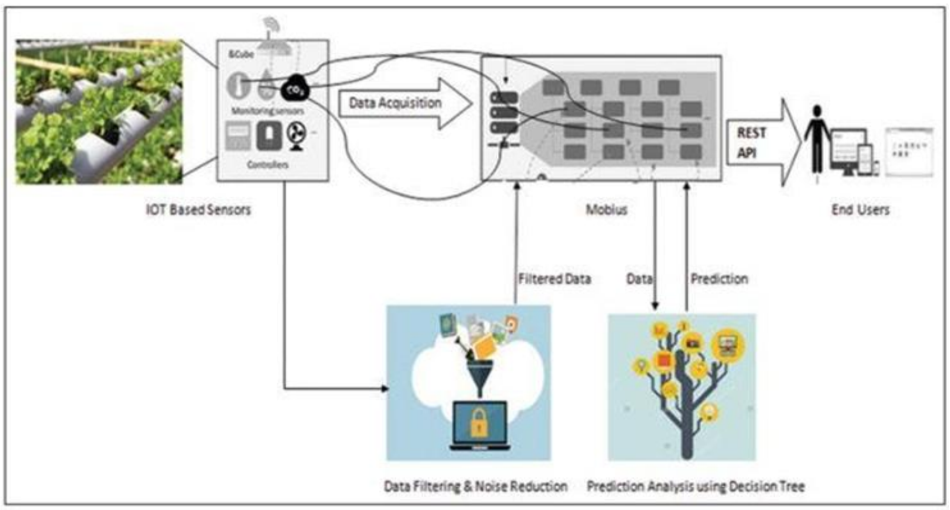

Figure 5 Patil et al architecture - Image taken from [17]

IV. Conclusion

This research successfully identified and analyzed trends, methods and architectures used in predictive analytics with IoT based on the research question posed with SLR between 2015 - 2019 in several popular journal databases. Based on the keyword formula, 674 papers were found, then by applying the inclusion and exclusion criteria, 30 papers were selected to be reviewed. The review results are as follows; trends in predictive analysis research fields with IoT are Transportation, Agriculture, Health, Industry, Smart Home, and Environment. Currently, agriculture is the most researched field such as plant disease prediction, plant growth monitoring, and stress prediction in dairy cows. The methods used in predictive analysis with IoT vary according to the data conditions used. There are five most widely used methods, namely Bayesian Network (BN), Artificial Neural Network (ANN), Recurrent Neural Networks (RNN), Neural Network (NN), and Support Vector Machines (SVM). Each method has a different level of prediction accuracy. Some researchers proposed improved methods from several methods. The improved method shows a better prediction accuracy rate. The results of this study also

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identified four kinds of proposed architectures namely Akbar et al Architecture, Abdulatif et al Architecture, Jo et al Architecture, and Patil et al Architecture.

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