International Journal of Future Generation Communication and Networking
Vol. 13, No. 3, (2020), pp. 1967–1976

Profile based Energy Management System for Smart Buildings: IoT and ML Approach

Dhanshree S. Barge [1], Anil R. Surve [2], Vijay R. Ghorpade [3]

[1]*Department of Computer Science and Engineering,
Walchand College of Engineering, Sangli, Maharashtra, India*

[2]*Prof. Department of Computer Science and Engineering,
Walchand College of Engineering, Sangli, Maharashtra, India*
[3]*Principal, Bharati Vidyapeeth's College of Engineering, Kolhapur, Maharashtra, India*

Abstract

In the recent survey, it has observed that building structures consume 32 percent of the country's total electricity in India. In developing cities, building energy demand is obvious to surge. It is necessary to cope up and synchronize the building operations intelligently for improvisation of the efficient and reliable whole energy systems. By virtue of a user's profile preference, energy consumption can be optimized using an appropriate machine learning approach. KNN machine learning algorithm can be instrumental in identifying profile, non-profile and combination of profile related to a human occupant in the smart space. This helps to improve energy performance standards for buildings to reduce energy utilization. Transparent, accurate and accessible electricity usage data for buildings is a primitive necessity for setting a baseline. The new scheme consents buildings to interconnect to their energy consumption with profile based preferences of users. This energy management system benefits smart buildings resulting in the overall cost consumption automatically and yet with more flexibility.

Keywords*: Internet of Things (IoT), Machine Learning (ML), K-Nearest Neighbor Algorithm (KNN), Artificial Intelligence (AI).*

1. Introduction

The population in an urban region of the world has increased rapidly from 751 million in 1950 to 4.2 billion in 2018 [1]. The building plays an important role in urban areas. The population increased from the last few years, as it was 6.8 billion in 2010 and it is predicted to be 7.6 billion in 2020. Large usage of energy is an estimated problem in the upcoming years. In future energy usage may be severe trouble for everyone. This problem arises not only because of an increase in population but also because of the rise in electrical appliances. Due to the large usage of appliances in the building, it demands high energy. Smart buildings are an effective and powerful source of competitive advantage. It interacts with inside building people, systems and external elements that present around them. To reduce the efforts for energy consumption while it ensures that the agreeable environment can also go towards the conflicts. Heating, ventilation and air conditioning (HVAC) and lighting-related appliances are meeting the basic requirements of people's comfort [3]. These are also important for most building energy consumptions, therefore the optimization of energy savings for a smart building while considering multiple comforts is essential. This way, the resultant model can further increase the improvement of its user experience and practicality. Some systems only automated electrical appliances but using the profile of a person is not much explored. There seems gravity to build a system that overcomes these limitations. So this is an attempt to devise an energy management system for smart buildings.

The Internet of Things is being used in almost all walks of life. Especially in Industry segments such as consumer IoT, profitable IoT, industrial IoT and Organization IoT. The number of IoT appliances

ISSN: 2233-7857 IJFGCN

increased by 31 percent to date. In 2015, it was 25 billion and the estimation is that there will be 50 billion appliances by the end of 2020 [2].

IoT-enabled smart buildings support a related and cost- effective user-level IoT application. These buildings consist of a larger part of IoT devices which can include HVAC, media, and security systems. Energy savings include long term benefits by automatically ensuring lights and electronics. These devices are turned off or on immediately. Smart building technology is the finest choice for people not only to upkeep about security, comfort but energy saving as well.

Smart building's energy management system connects to existing infrastructure and uses IoT sensors to monitor energy consumption. Saving energy is an increasingly essential concern in current times. Smart building instrumented device systems advantage to energy utilization and reliability by allowing users in the loop with the advent of ML algorithms in novel ways with focusing the comfort of people.

Energy consumption requires notably large attention worldwide. This paper is an attempt in this regard using a profile base for energy management, employing the latest techniques in IoT and ML.

2. Literature Review

[1] F. G. Brundu et. al., "IOT Software Infrastructure for Energy Management and Simulation in Smart Cities"

The related research of the system proposed new policies that enabled for management of energy and simulation. Using the application layer and technologies integration layer the energy distribution performed with different IoT devices. The deployment of a platform for the heating distribution network has been established and verified in a real-world area and original control policy.

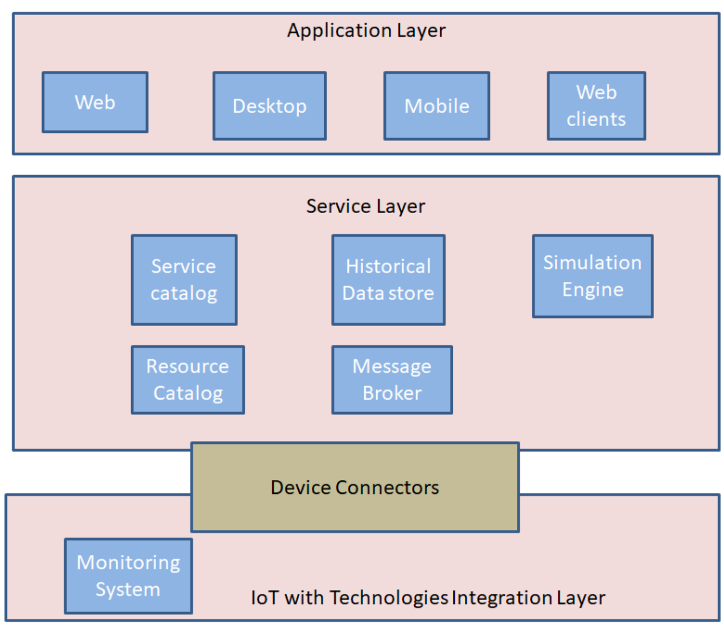

Fig. 1. Architecture with energy management and simulation.

ISSN: 2233-7857 IJFGCN

Fig. 1 shows the infrastructure with multiple layers and each layer consists part of the integration. Service layer and IoT with technology layer connect using device connectors. First layer with the devices and web. The service layer consist of various catalog, store the historical data, server and simulation engine. The author used this approach in smart cities.

[2] D. Minoli, K. Sohraby, B. Occhiogrosso, "IOT Consideration, Requirement, and Architecture for Smart Building-Energy Optimization and Next-Generation Building Management System"

The author has represented a review of the current building management system (BMS) and next-generation BMS. The methods and Open System IoT Reference Model (OSiRM) technique for on IoT and it highlights the importance of security. Based on criteria HVAC controls, it also designed smart lightning which remotely accessible.

Parameter	**Current BMS**	**Next-generation BMS**
Scope	Service-specific to given building function	Multiservice fully integrated functions
Sensor	Function specific Sensors	Motion, Humidity, Temperature, Face recognition sensors
Access	Closed/Local	Open/Remote
Security	Basic	Advance
Architecture	Closed, Standalone	Open, Networked

TABLE I. Comparison between Current BMS and Next Generation BMS

Various parameters are useful for the measurement of current and next-generation BMS which gives better results with comparison as shown in Table I.

[3] T. Wei, Q. Zhu, N. Yu, "Proactive Demand Participation of Smart Buildings in Smart Grid"
The author has concluded the Demand Bid Curve algorithm that has been used to specify a customer's energy consumption. Smart meters and two-way communication systems used for energy consumption. Building thermal dynamic model equations used for an accurate result. Research review shows one ratio which effects proactive-demand-response for analysis and result comparing with algorithms.

[4] A. Basit et. al., “Efficient and Autonomous Energy Management Techniques for the Future Smart Homes”
The system design elevated performance on smart city and constructed on IoT invention modes, services R & D stage model. Many cutting edge technologies such as renewable energy applications used and

ISSN: 2233-7857 IJFGCN

presented on an innovation management structure that authorizes IoT for good backing sustainability of smart city/building development.

[5] E. Mocanu et. al., "On-Line Building Energy Optimization Using Deep Reinforcement Learning"

A review of solution that reduces the cost of energy management for peak load times using the home system. The system formulates and optimizes the problem and different practical limitations, which shown to be mixed inter programming problems, crack by using Dijkstra´s algorithm, gives much lower complexity. The system presented a simulation result which shows performance and complexity comparison with different solution & existing methods.

[6] L. Martirano et. al., "Aggregation of Users in a Residential/Commercial Building Managed by a Building Energy Management System (BEMS)"

The author has designed a system for the exploration of a smart grid context that benefits using deep reinforcement learning. Research performed online optimization schedulers for building energy management i.e. combination of reinforcement learning and deep learning. It also shows an approach that a large scale database can be validated. This database is highly dimensional and that consists of data for power generation & building appliances.

[7] H. Jayakumar, A. Raha and V. Raghunathan, "Energy-Aware Memory Mapping for Hybrid FRAM-SRAM MCUs in IoT Edge Devices"

Discussion of approach that easy way to understand demand-side management for residential/commercial buildings, which gives tractability of smartness in appliances in buildings. It presents the important aspects of the control system and graphs are given with results and case studies.

[8] C. Guven, K. Akkaya, and A. Kadri, "Occupancy Counting With Burst and Intermittent Signals in Smart Buildings"

The researcher suggests multiple techniques assigned in IoT edge devices for energy-aware memory mapping of program units. It consists of a technique, called Energy-Align, that aligns purpose and power cycle borders thereby attaining energy presentation benefits published in International Conference on VLSI Design and on Embedded Systems.

[9] A. R. Surve and V. R. Ghorpade, "Pervasive Context-Aware Computing Survey of Context-aware ubiquitous middleware systems"

The concepts of context computing, pervasive computing and generic life cycle of context-aware computing, also context-aware features and levels which gives a brief survey on middleware support for context-awareness and middleware technologies.

[10] A. Surve, A. Khomane, S. Cheke, "Energy Awareness in HPC: A Survey"

In the high performance of computing the power control and management is a challenge for cost as well as energy. Energy consumption is key in high performance of computing to build in an efficient way with techniques. For consideration and architecture of smart buildings, new policies have been used. The demand bid curve algorithm shows the connection between energy usage and energy conservation. Not only performance but also complexity are the major aspects of energy conservation. Different deep reinforcement learning shows the online optimization with large scale, which provides the flexibility.

ISSN: 2233-7857 IJFGCN

3. IoT with ML Technologies

Having seen the research exploration by relevant research attempts, it would be appropriate to seek the multiple latest domains which aim to boost the proposed endeavor which is enlisted as follows,

1. Internet of Things
2. Machine Learning
3. Convolutional Neural Network
4. Artificial Intelligence

Based on which the system is designed for a smart energy-conservation with the main motive to cater to the profiled user comfort in a single or multi-user building environment.

The major system tasks are to learn from IoT enablement's for smart building, identify user profiles and accordingly design system with appropriate machine learning algorithms heuristically to achieve energy consumption. Also evolve research implementation for improving building efficiency, reliability, usability and energy optimization metrics. Other aspects are to analyze system performance in terms of ambience, resilience and related quality of service.

The term Smart Building is coined for a reduction in energy consumption, improved overall building efficiency and assisting predictive maintenance.

A. Methodology

The IoT enabled system is devised to cater mainly following four situations,

- Profile user with high preference.
- Profile user with low preference.
- Combination of profile users with high and low preference.
- Non-profile user

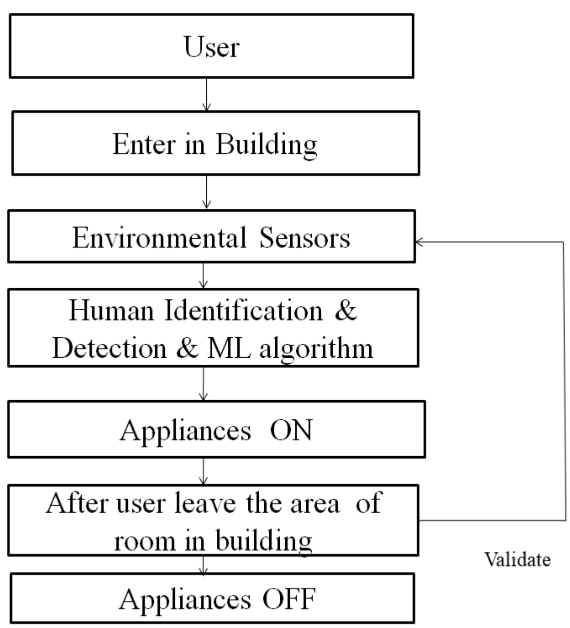

Fig. 2. Generic use case of the system

ISSN: 2233-7857 IJFGCN

As shown in Fig. 2, in the generic use case, when a user enters into the instrumented room of building then using a motion detection sensor, the system detects that someone is present. After capturing a photograph in the camera, the system identifies users and checks whether the user has assigned any preference as per the current context information. Achieving this, the system employs IoT and machine learning techniques to facilitate the user. The system is trained to work according to the context profile base preferences. The system works for registered users as aimed and for non-registered users, it works in the default case. After creating a profile based on the preferences of the user then it will provide services automatically. By virtue of this, the system not only saves energy but also provides comfort to the users.

B. Machine Learning Algorithm

For a combination of profile users with the high and low preference-based system, machine learning algorithms are beneficial.

KNN (K-Nearest Neighbor) algorithm is useful when different profiled users are allowed and eventually entered into the building. This supervised machine learning algorithm is appropriate for solving both classification and regression problems. Also, ANN and SVM techniques lead to an improvement in the performance of the energy management. SVM algorithm acts as a binary classification method in supervised machine learning.

4. IoT and ML Confluence

Using IoT instrumentation and machine learning techniques, the aimed system is made functional. Fig. 3 depicts the major components of the system architecture enablement.

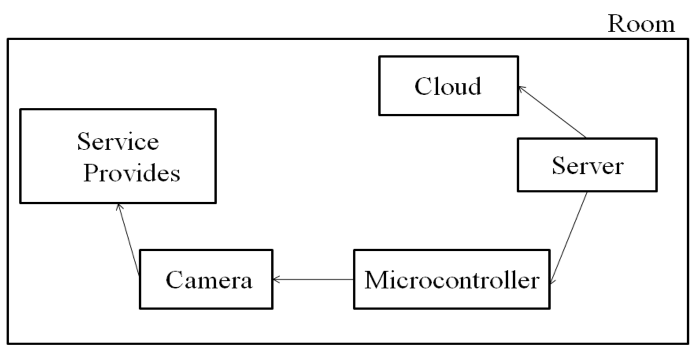

Fig. 3. Connection of system

In a typical sequence, the camera connected to a microcontroller captures the image and the user's face gets recognized with the aid of the KNN algorithm using the data set which is stored on the IoT cloud platform. The context-server is meant for connectivity which provisions services in the room which is also denoted as active space.

ISSN: 2233-7857 IJFGCN

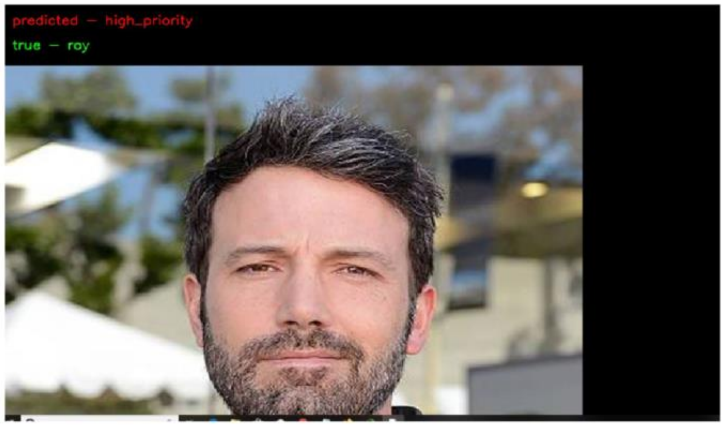

Fig. 4. A snapshot of the face recognition result

The KNN algorithm employed for face recognition seems better in terms of result accuracy as compared to the SVM algorithm. Such a result is shown in Fig. 4. For these experiments, the data set is separated into high and low preference images. When an image does not match then the system considers it as a non-profile user. The system provides services that automate the instrumented appliances to switch ON/OFF as per application logic. For high and low preference AC and fan are ON/OFF respectively. The system is thought of as energy conservation situations as per change in context conditions also.

The IoT context awareness is employed using sensors, camera modules, etc which are connected to microcontrollers such as Raspberry pi or Arduino. The electrical appliances are operational with actuators and relays in the system.

A. Comparison

Extending the experimentation, for face recognition two methods used, first noted as normal face recognition which was without IoT standard platform support and method 2 with AWS standard face recognition services. A comparison between Method 1 and Method 2 is briefed in Table II.

Parameters	**Using Method 1 (Normal face recognition)**	**Using Method 2 (AWS)**
Face Recognition	Correctly identified also depends on the data set.	Correctly identified also better results than method 1.
Efficiency	Less than comparing to AWS but better results for understanding.	Well architected Framework.
Reliability	It is better reliable using with modifications.	AWS monitors runtime metrics, With using "I AM" user enables secure access.
Usability	User friendly but with large code for development. The user is friendly with customers.	User friendly with a dynamic approach, Cloud Watch logs console (user can share the state of their log sessions).

TABLE II. Comparison of Face Recognition Methods.

ISSN: 2233-7857 IJFGCN

AWS, open-access cloud services provided better results due to its proven methods while using a normal face recognition method is helpful where implementation feasible without cloud support.

B. Graph Representation

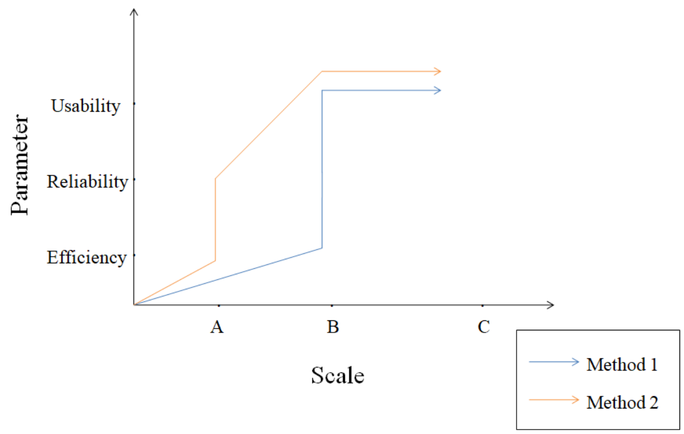

Fig. 5. Representation of graph for methods 1 and 2.

Using AWS cloud for face recognition with the parameters as efficiency and reliability were observed better than face recognition without the cloud platform. Both methods found user friendly. Fig. 5 shows the various parameters with scales A, B, C for high, medium, and low respectively.

C. Energy Consumption

This is a learning algorithm which utilized in machine learning. A neural network, once used for classification, is usually a set of neuron-like process units with weighted connections between the units. They accommodate different layers for learning and analyzing information. It consists of three layers hidden layer, input layer, and output layer.

<table>
<tr><th>Month</th><th>Billing Unit</th><th>Energy Consumption in Percentage</th></tr>
<tr><td>August-2019</td><td>45 (without the profile base system)</td><td rowspan="4">60 % (considering only for 6 months)</td></tr>
<tr><td>September-2019</td><td>66 (without the profile base system)</td></tr>
<tr><td>October-2019</td><td>50 (without the profile base system)</td></tr>
<tr><td>December-2019</td><td>42 (with the profile-base system)</td></tr>
</table>

ISSN: 2233-7857 IJFGCN

January-2020	30 (with the profile-base system)	
February-2020	29 (with the profile-base system)	

TABLE III. Comparison of energy consumption

The observation was drawn in the profile base energy management system which was configured in a context is shown in Table III. For the prior three months into consideration without using a profile base system, table shows a major reduction in the billing unit as compared to without the profile base system. The energy consumption using this system gives 60% for six months from August to February.

5. Challenges and Opportunities

The experimentation system explored only for traditional methods and not based on the actual profile system. New algorithms in ML such as KNN, SVM are useful for predicting accuracy. Due to the increasing appliances in the building, it requires energy scheduling and related quality of service which is responsible for energy management accordingly.

6. Conclusion

This research attempt has explored the IoT enabled platform for smart buildings with energy efficiency. The system utilizes the flexibility of building requirements in an automated fashion. At the building level, ML algorithms and sensor based context aware system using IoT is employed intelligently which caters to the preference base system. The system also observed energy management with profile base users which are beneficial for energy utility and consumption for smart spaces.

Acknowledgment

We express our sincere gratitude towards all authors of whom research papers and datasets are referred for our research efforts. We are also grateful to our institute which facilitated us in accomplishing this research and eventually compiling this artifact too.

References

[1] F. G. Brundu et al., “IOT Software Infrastructure for Energy Management and Simulation in Smart Cities,” *IEEE Transaction On Industrial Informatics.*, Vol. 13, no. 2, pp. 832-840, April 2017.
[2] D. Minoli, K. Sohraby, B. Occhiogrosso, "IOT Consideration, Requirement, and Architecture for Smart Building-Energy Optimization and Next-Generation Building Management System," IEEE Internet Of Things Journal., Vol. 4, no. 1, pp. 269-283, February 2017.
[3] T. Wei, Q. Zhu, N. Yu, "Proactive Demand Participation of Smart Buildings in Smart Grid," IEEE Transactions On Engineering Management., Vol. 65, no. 5, pp. 1392-1406, May 2016.
[4] A. Basit, et.al., “Efficient and Autonomous Energy Management Techniques for the Future Smart Homes”, IEEE Transactions On Smart Grid, Vol. 8, no. 2, March 2017.
[5] E. Mocanu et.al., “On-Line Building Energy Optimization Using Deep Reinforcement Learning,” IEEE Transactions On Smart Grid, Vol. 10, no. 4, pp. 3698-3708, July 2019.
[6] L. Martirano et.al., “Aggregation of Users in a Residential/Commercial Building Managed by a Building Energy Management System (BEMS)”, IEEE Transactions On Industry Applications, Vol. 55, no. 1, February 2019.

ISSN: 2233-7857 IJFGCN

[7] H. Jayakumar, A. Raha and V. Raghunathan, "Energy-Aware Memory Mapping for Hybrid FRAM-SRAM MCUs in IoT Edge Devices," International Conference on VLSI Design and on Embedded Systems, 2016.
[8] C. Guven, K. Akkaya, and A. Kadri, "Occupancy Counting With Burst and Intermittent Signals in Smart Buildings," IEEE International Journal on Internet Of Things, 2018.
[9] A. R. Surve and V. R. Ghorpade, "Pervasive Context-Aware Computing Survey of Context-aware ubiquitous middleware systems," International Journal of Engineering, January 2017.
[10] A. Zanella et. al., "Internet of Things for Smart Cities," IEEE International Journal on Internet Of Things, 2014.
[11] W. Wen, "Research on the Key Technologies ofIoT Applied on Smart Grid," School of Electrical Engineering, Wuhan University, Wuhan, China, 2015.
[12] A. Al-Ali, I. Zualkernan, M. Rashid, R. Gupta, M. AliKarar, "A Smart Home Energy Management System Using IoT and Big Data Analytics Approach," in IEEE Transactions on Consumer Electronics, Vol. 63, no. 4, pp. 426-434, November 2017.
[13] J. Choi, Y. Shin, M. Choi, W. Park, and I. Lee, "Robust Control of a Microgrid Energy Storage System using Various Approaches," in IEEE Transaction on Smart Grid, Vol. 7, no. 4, July 2018.
[14] Q.Wan, Y. Teh, Y. Gao, and P. Mok, "Analysis and Design of a Thermoelectric Energy Harvesting System With Reconfigurable Array of Thermoelectric Generators for IoT Applications," in IEEE Transaction on Circuits and System–I: Regular Paper.
[15] S. Yoshida, S. Izumi, H. Kawaguchi, and M. Yoshimoto, "Energy-Efficient Spectral Analysis Method Using Autoregressive Model-Based Approach for Internet of Things," in IEEE Transaction on Circuits and System–I: Regular Paper, Vol. 66, no. 10, October 2019.
[16] J. Bito, R. Bahr, J. Hester, S. Abdullah Nauroze, A. Georgiadis, and M. Tentzeris, "A Novel Solar and Electromagnetic Energy Harvesting System With a 3-D Printed Package for Energy Efficient Internet-of-Things Wireless Sensors," in IEEE Transaction on Microwave Theory and Techniques, 2017.
[17] S. Mondal, R. Paily, "Efficient Solar Power Management System for Self-Powered IoT Node," in IEEE Transaction on Circuits and System–I: Regular Paper, 2017.
[18] Cvc T. Kannan et al., "Energy Management Strategy for Zone Cooling Load Demand Reduction in Commercial Buildings: A Data Driven Approach," in IEEE Transactions on Industry Applications, 2019.
[19] K. Cao et al., "QoS-Adaptive Approximate Real-Time Computation for Mobility-Aware IoT Lifetime Optimization," in IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems, 2018.
[20] A. Surve, A. Khomane, S. Cheke, "Energy Awareness in HPC: A Survey," in International Journal of Computer Science and Mobile Computing, Vol. 2, pp. 46-51, March 2013.

ISSN: 2233-7857 IJFGCN