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Social Internet of Things (SIoT) Enabled System Model for Smart Integration of Building's Energy, Water and Safety Management: Dhaka City, Bangladesh Perspective

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***Abstract*— Dhaka, being the largest township of Bangladesh City Buildings is excreted by in-migration, a rapid growth of population, withering of living and infrastructure standard, which eventually is threatening overall sustainability and well beings. Modernization and digitalization of building infrastructure is not only an important step towards resolving the problems but also it will be a facilitator for smart, efficient and optimized urbanization. On May 2018, the authors conducted a survey among 51 Residential Building's owner/building managers, 25 Non-residential Building's owner/building managers and 25 corporate building's owner/building managers to find market adoptable IoT solutions for building's smart efficient energy, water and safety managements. The features requested in this survey are optimized and implemented by the authors and finally, here the system model with simulation results is presented. This system shows promising energy, water resource management optimization and some intriguing factors that validate its objectives, social characteristics, market usability.**

Keywords*— *SIoT, SBMS, Cyber Physical system, Multi- agent system, OSiRM;

I. Introduction

Social internet of things (SIoT) paradigm galvanize social objects, not smart objects with an intension to disparate people and things: objects get their own social networks for interaction and collaboration, people impose regulations to secure privacy, get to ingress the throughput [2]. Also, it has this capability to create this ecosystem, where actually people have social interaction within, create real social values. Currently, at 2018, among the 4.021 billion internet users worldwide, 3.196 billion are social media users. Also, currently number of mobile phone users is 5.135 billion [3].

It is really inspiring for adopting social network enabled infrastructure powered by the mobile phone centric Internet of Things (IoT) model. Andreas et al explored the possibilities of leveraging existing social networking managements to enhance social experience with the smart home [4]. The authors here study a very different approach, which suggest a micro social network entity in a smart building management, which doesn't require complying with existing social networking sites. So the problem of interoperability among the SNS (social networking sites) addressed in [4] is resolved. However, true novelty of the system lies with its features, projecting definite applications. A recent study by Mussab et al [5] reviewed numerous papers on smart home applications with IoT such as automated transportation, smart closed circuit television (CCTV), energy management system applications, network architecture, mobile apps, security applications, and environmental monitoring systems etc. and also their system analysis, technology prospects. But all these applications may not be viable for Dhaka city, Bangladesh, considering its technological inferiority, market, consumer psychology and overall economy. Unfortunately, currently the buildings in Dhaka don't concentrate on modernization and sustainability. Khalid et al in one study of 2014 claim; government in Bangladesh has not adopted sustainable building and building energy codes in any form, despite the fact worldwide buildings are responsible for 30%-40% consumption of energy [6]. Now, it is very promising that in April, 2018, Bangladesh Telecommunication Regulatory Commission (BTRC) issued a directive legitimizing Internet of things (IoT) incorporating 'Smart Building' amongst one of the nine sectors where IoT can revolutionize [7]. Digitalized building management such as BMS (building management system) is a reality in many countries. BMS automate most facilities and operations in a building in an optimal and efficient; though require expensive maintenance and implementation. Smart BMS (SBMS) are recent trend now, which embrace and adopt more robust, advanced IT architecture ensuring improved functionality and overall performance [8].

Here authors simulated a SIOT empowered SBMS, backed by the conducted survey at [1]. This SBMS integrate energy management, water management and safety management. The survey was conducted in three types of buildings: residential, non-residential and commercial. A general model is implemented here, which can be adopted on the mentioned three types of buildings. Smart buildings enactment can ensure up to 30% savings of water usage, 40% savings in energy use, also save building maintenance cost by 10 – 30% [9]. The Open systems IoT Reference Model (OSiRM) presented by Daniel et al [10] with these 7 layers; Things, Data Acquisition, Fog Networking, Data Aggregation, Data Centralization, Data Analytics & Storage and Applications is a core inspiration here

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for the model development. Simply a Sensor-Actuator-Internet framework building on www (static pages web) to web2 (social networking web) to web3 (ubiquitous computing web), creating a platform where sensing and analyzing data on a grand scale and with internet as the medium, materializing intelligent operation of actuators is accomplished. The building system management here is not only a micro social network for the things but for the associated people/ consumers.

The authors, committing to their conducted survey, tried to achieve the cost per floor of the building within 240 US Dollar.

II. SYSTEM MODEL WITH EXPERIMENTAL SETUP

The system model is developed on the survey study conducted by the authors. The survey participants were the owners from residential, non-residential and commercial buildings. They confirm the type of the building. The format of this survey and the participants list with their signatures, definite question's answers are available in this link: goo.gl/u3mF2W. The survey was necessary to explore marketable IoT solutions for buildings and basing on that the system model here is proposed and demonstrated. A general scenario is portrayed here is of a five-storey building. It has four floors. First floor is owned by the owner, who is the targeted consumers of the SBMS. This floor can be the management office of a commercial building. In the other floors, the tenants reside, or for commercial buildings, these floors can be employee hub contributing to the organization. Each floor has One Bedroom/ One common room, one kitchen and One Bathroom.

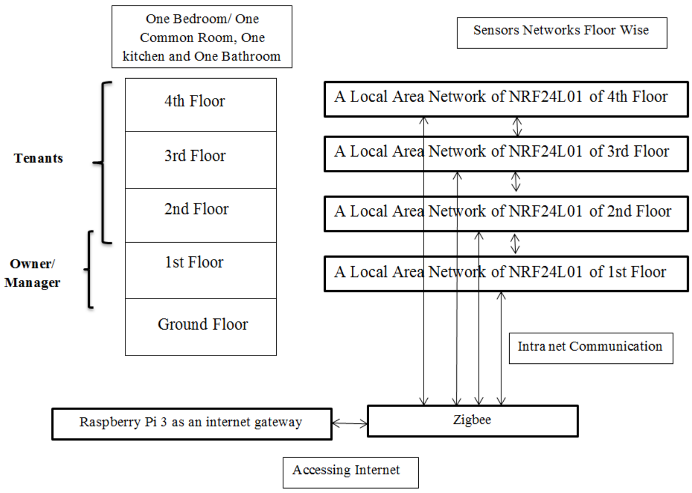

Fig. 1: Related Communication Network infrastructure of the IoT system model of 5 Storey Building

In a floor, these 3 blocks will be IoT enabled. In each block, sensory systems, processor MCU (328p), NRF24L01 modules making a small social local area network (SLAN) are laid out.. SLAN from 4th floor and 3rd floor communicate will a Zigbee module, which rest on the 2nd floor. The LAN from 2nd and 1st floor also communicates with the same Zigbee module. This Zigbee module communicates with Raspberry Pi the main data processing unit and internet gateway in the ground floor. Related communication infrastructure is given in Fig.1. The IoT enabled switchboard on each floor will be responsible for controlling of the load and measure its consumption.

A. SBMS Energy Management System:

This system management has the potential to bring positive change by reducing carbon emission, securing energy supply, optimizing energy consumption. Martin et al integrated smart metering, smart grid and home automation system to achieve this [11]. This inspired this model here for smart metering with an added advantage to shape consumer behavior. A recent study reviewed Internet of Things solutions for intelligent energy control in buildings for smart city applications mentioning these important challenges for IoT system design: reliability, mobility, interoperability, scalability, availability, security, big data analytics, cloud computing, low-power and modular sensor nodes design [12]. Making the system context-aware was an objective, which actually features its capability to provide relevant services and information to the users based on their situational conditions (i.e., contexts) [13]. RF enabled wireless sensor network (WSN) is used other than more efficient and popular Zigbee enabled WSN, to compromise on the cost issues. BEMOSS agents developed by Virginia Tech have been a good inspiration for the adoption of multi agent structure in the proposed model. It has these similar concerns, 'plug & play', 'interoperability', 'ability for remote control and monitor', 'cost effectiveness' 'open source open architecture' [14].

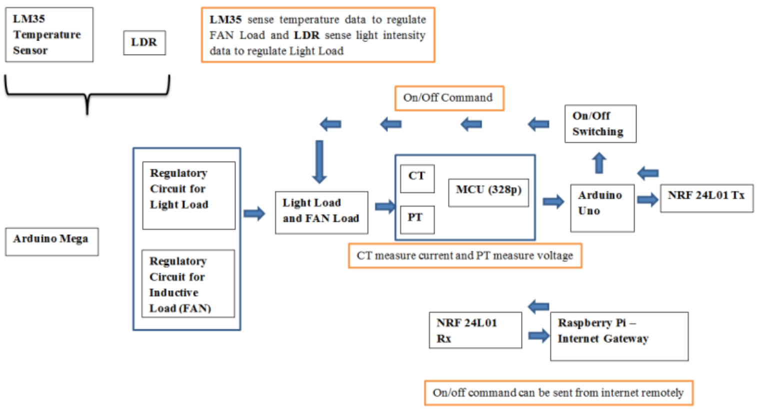

Fig. 2: Complete Management of the experimental set up of SBMS Energy Management

From the survey [1], these features are requested by the participants and optimized by the authors:

- Metering and billing of Energy consumption floor wise
- Electrical load status on Bedroom and warning system
- Display of Comparison with previous week daily consumption and billing to effect consumer behavior
- Remote control of load of Bedroom
- Occupancy sensor based light load control to save electrical energy

- Human presence detection based controlling of electrical load to reduce overconsumption of energy

In the experimental setup, this SBMS energy management is demonstrated for one floor as each floor has presumed same infrastructure. The sensory systems have 2 types of sensors: LM35 temperature sensor and light dependent resistor (LDR). LM35 will collect data which will facilitate the decisions regarding Fan load and LDR will measure the amount of lux to determine how luminous the home environment is.

Arduino mega processor is used to process the data from sensory management responsible for evaluating the environment. Light load and Fan load are two of the major loads that are very common in a building. There are 2 different regulatory circuits for these two types of loads. Process data from the arduino are the input of this regulatory circuit, which regulate the loads for automated control of consumption of energy.

The load's energy consumption is also monitored via another sensory management consisting with current transformer (CT) and potential transformer (PT). CT is responsible for measuring current consumption and PT is responsible for measuring voltage consumption. Here data gathered regarding this is process in a microcontroller unit (328p). NRF 24L01 is used as the WSN nodes. The Raspberry pi is utilized as the internet gateway and the central processing unit.

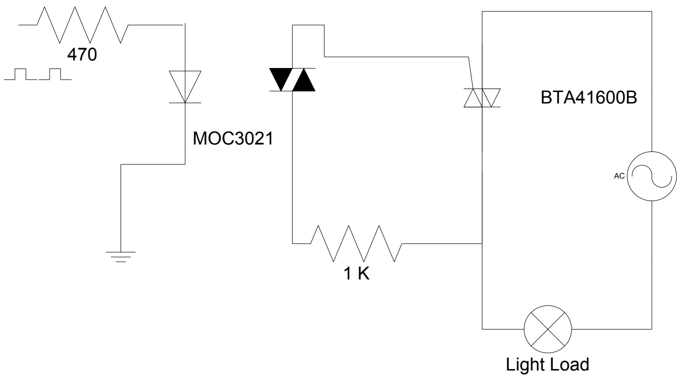

Fig. 3: Regulatory Circuit for Light Load

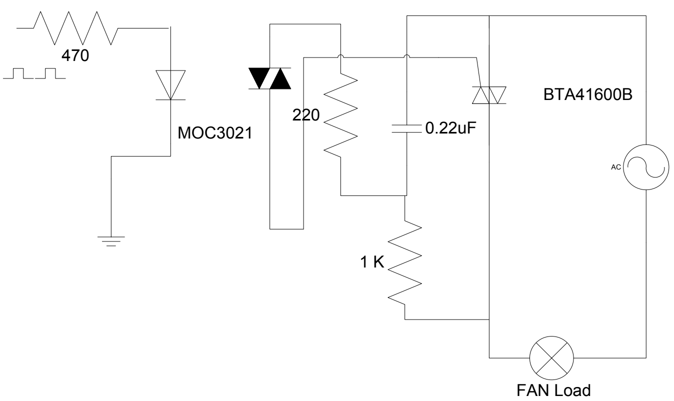

Fig. 4: Regulatory Circuit for FAN Load

Fig. 3 and 4 here, presents the regulatory circuits to regulate light load and fan load. These circuits are implemented. Opto-Isolator MOC3021 is used to isolate DC from AC and pave the way to modulate it according to the decisions provided by the processor. TRIAC BTA41600B is used to control current. For inductive load snubber circuit is implemented in the regulatory circuit.

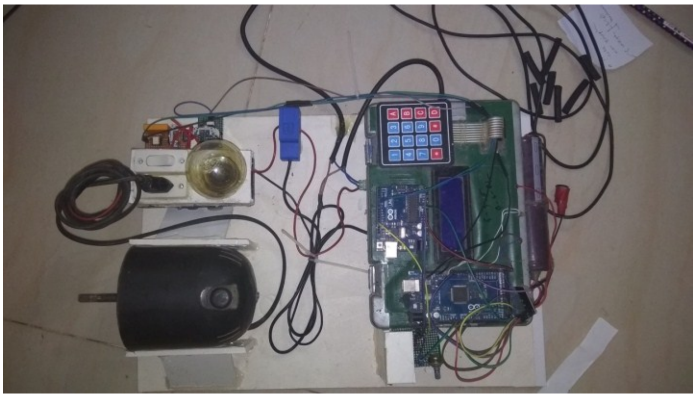

Fig. 5: Primary experimental set up for SBMS Energy Management System

The outcome of this management is presented in the later section.

B. SBMS Water Management System:

IoT enabled water management system is introduced commercially in India, known as watersenz by a Startup organization gnarun solutions. It has application, consumption analytics and other services [15]. This inspires the management of this system. Appliance level water consumption and governing people's water usage behavior resulted in ISS-EWATUS (www.issewatus.eu), a European Commission funded FP7 project is promising [16]. The exact consumption time and amount is recorded for efficient shaping of behavior. From the survey [1], these features are requested for water management by the participants and optimized by the authors:

- Water flow sensing in the Bathroom faucet, to detect over consumption. Over consumption is a sure result, if someone forgets to close water tap. This system will be timed to realize and send necessary alarm to authority.
- Tank level monitoring to automatically control the motor
- Metering and billing of water consumption floor wise
- Generating alarm or warning towards over consumption to effect consumer behavior
- Display of Comparison with previous week daily consumption and billing to effect consumer behavior

Here in the proposed SBMAS water management system, water consumption is achieved by introducing single monitoring sensor for single floor. It is inspired by a study done by James et al, where water consumption was monitored by using fixture recognition by random forest algorithm [17]. In the experiment, G1/2" Water Flow sensor (Model - SEN-00043) is used. The logic behind the exact monitoring is, each water consumption point is in different position from the water inlet to the floor. The sensor is placed in the water inlet measuring real time water flow rate. It varies for different water consumption point. Detecting that depicts water consumption for different consumption point. Over consumptions are also realized by this and alarm/ notifications are send to govern consumer behavior.

Fig. 6: G1/2" Water Flow sensor (Model - SEN-00043) for SBMS Water Management System [18]

The outcome of this system management is presented in the later section.

C. SBMS Safety Management System:

In building, there are several safety issues: fire safety, theft of assets, unauthorized entry of criminal personal etc. Adopting IoT can materialize these features. In Dhaka city fire hazards has a frightening statistics. The number of fire incidents becomes tripled in the last two decades, from 5,376 in 1996 to 18,105 in year 2017 [19].

Fig. 7: Primary experimental set up for SBMS Safety Management System

Again, from the survey [1], these features are requested for safety management by the participants and optimized by the authors:

- CCTV Camera feed to the authority.
- Detecting unauthorized entry
- During earthquake or fire, instant alarm, safety instruction to the residents, alarm notification to the respective authority

The authenticity of this system is demonstrated by interfacing camera with Raspberry pi to monitor unauthorized entry, interfacing sensors to detect earthquake or fire hazard. One of the main functionality is again to shape consumer behavior, response to hazard, acting as a guide through these situations.

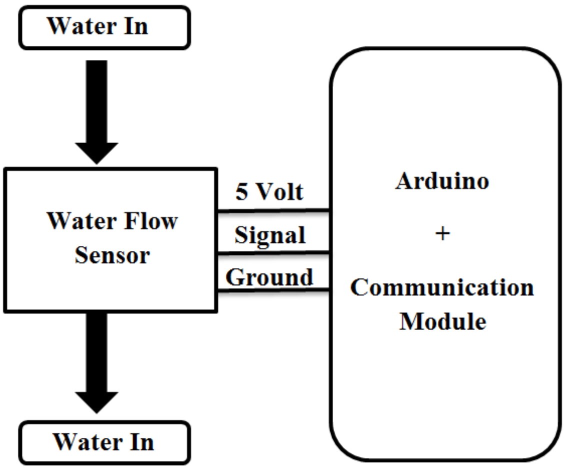

Fig. 8: Block Diagram for SBMS Safety Management System

D. SBMS Micro Social Virtual Interface:

To make SBMS more social, its virtual interface collaborate features that positively contribute to that purpose. A virtual intercom communication system is introduced with which, the residence can communicate with each other via voice call, voice messaging or text messaging. Owner can post important/emergency notice to the tenants. This whole management will be smart phone driven. The mobile application interface for owner and tenants will be different. Both parties will have different account. Owner account has these characteristics:

- 3 web panels: One, status display panel, another communication panel and final one is control panel.
- Status display panel will display metering, billing of water and energy consumption, comparison with last week's metering, billing of water and energy consumption, load on off status, overconsumption alarm, safety alarm, CCTV camera feed, alarm of unauthorized entry
- Communication panel is for owner to put notices for the tenants, communicate with the tenants via text message and voice call

- Control panel is for controlling electrical load, to monitor and hinder overconsumption of energy and water.

Tenant account has these specifications:

- 3 web panels: status display panel, communication panel and control panel.
- Status display panel will display metering, billing of water and energy consumption, comparison with last week's metering, billing of water and energy consumption, load on off status, overconsumption alarm, safety alarm, CCTV camera feed, alarm of unauthorized entry
- Communication panel is for tenant to communicate with others of the building via text massage, voice message, voice call
- Control panel is for controlling electrical load, water load, to monitor and resist overconsumption

This overall virtual interface, being cell phone centric has these attributes, which make it an extension of the building and its resident's individually, also communality.

III. SYSTEM SIMULATION RESULTS

From the experimental setup of SBMS Energy Management system, the generated and calculated data are plotted on MATLAB. Fig. 9 – Fig. 12 represents real time data plot of apparent power consumption, current, power factor variation and real power consumption without IoT management. These data are collected, while the sensing agents are not working and no regulation of load to reduce consumption is done. Without IoT Control Apparent Power varies over time: 60 VAR – 85 VAR, Control Current varies over time: 0.25 A – 0.3 A, Control Power factor varies over time: 0.8 – 0.98, Control real power over time: 66W – 73 W.

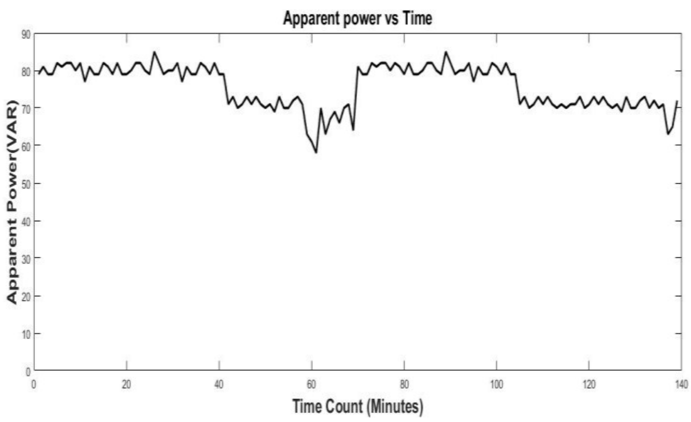

Fig. 9: Apparent power consumption in a definite time period (Without IoT)

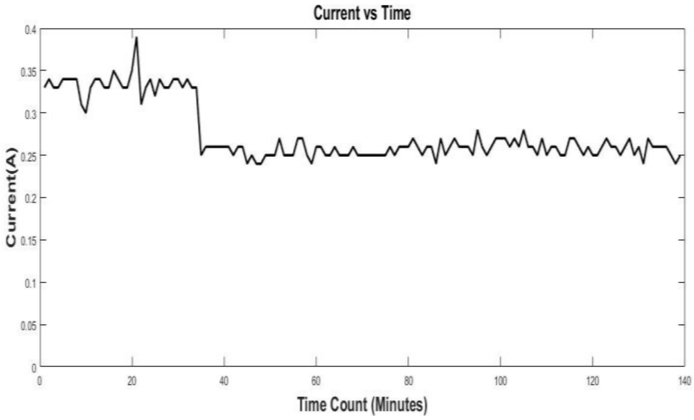

Fig. 10: Current consumption in a definite time period (Without IoT)

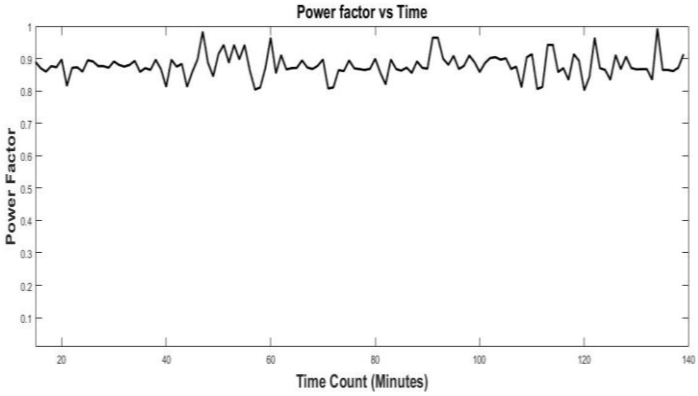

Fig. 11: Power factor variation in real time (Without IoT)

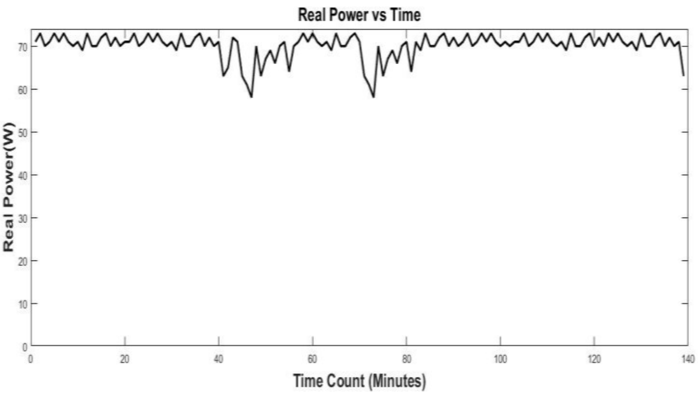

Fig. 12: Real Power consumption monitoring real time (Without IoT)

From the experimental set up, later data was collected after regulation by IoT control. The results show energy consumption and validating the system's affectivity. Fig. 13 – Fig. 16 represents real time data plot of apparent power consumption, current, power factor variation and real power consumption with IoT management. This shows consumption of energy regulated by the sensing agents. With IoT management, Control Apparent Power varies over time: 60 VAR – 72 VAR, Control Current varies over time: 0.25 A – 0.27 A, Control Power factor varies over time: 0.68 – 0.75, Control real power over time: 32W – 47 W.

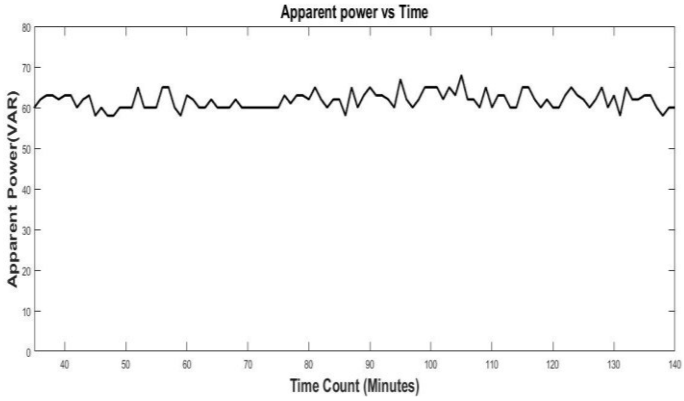

Fig. 13: Regulated Apparent Power consumption in a definite time period (With IoT)

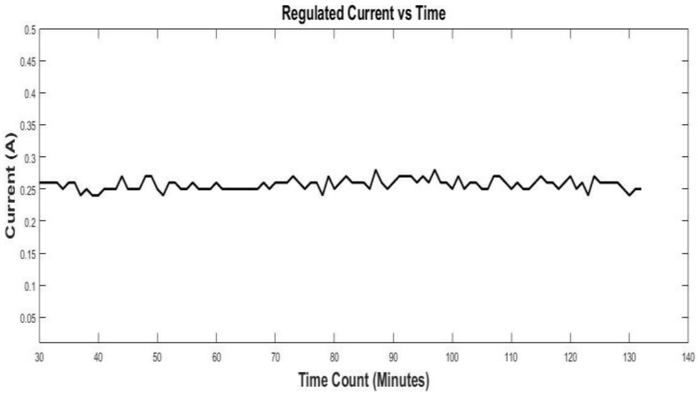

Fig. 14: Regulated Current consumption in a definite time period (With IoT)

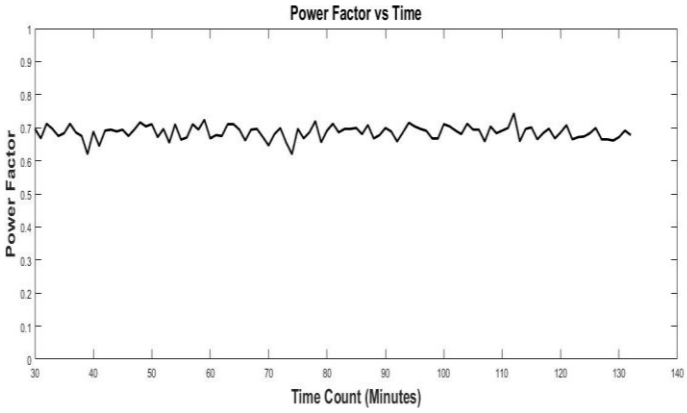

Fig. 15: Power factor monitoring in a definite time period (With IoT)

In SBMS management experimented here, have these following observation,

- Significant reduction of power in a definite time dictates lower energy consumption
- Power factor reduction is observed, but apparent power is lower. So the loss is lower. It is because after IoT control electrical energy supplied got reduced
- NRF communication is low cost but not efficient
- TRAC switching performs better with higher frequency operation of the Microprocessor

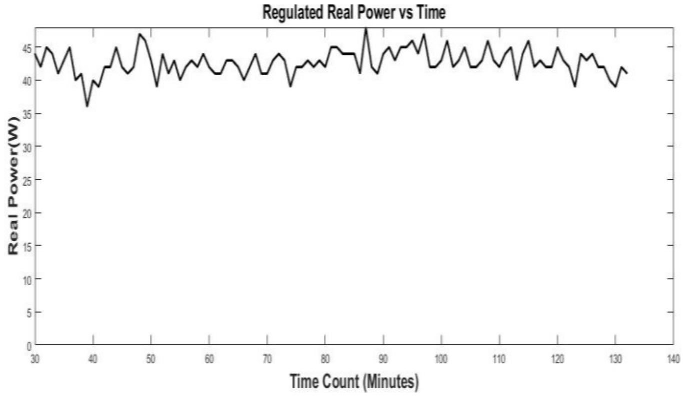

Fig. 16: Regulated real power consumption in a definite time period (With IoT)

SBMS Water management system also produces water flow rate data, which dictate the system to achieve water consumption monitoring.

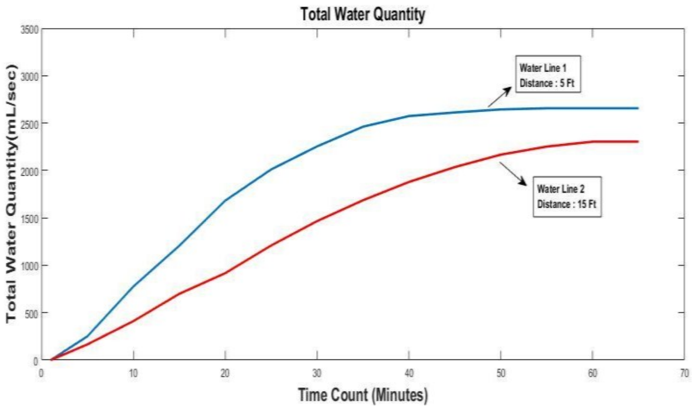

Fig. 17: Water flow rate data plot real time

Different fixtures are observed for different faucets on Fig. 17, which indicate possibility for determining consumption for different faucets. SBMS Safety Management shows positive results, regarding demonstration. The data here is video data for detecting unauthorized entry. Smoke sensors implemented fire hazard detection is a very popular scheme. Real Time water flow Data was collected from 2 difference. In Fig. 17, it is assumed these 2 water flow are from 2 fixtures in 2 different distances.

IV. Evaluation and Validation of the System

The proposed system implemented features that are requested by the participants of the survey [1]. Here are some discussion on the evaluation and validation of the system in different aspects.

A. Technical Evaluation:

The experimental study shows less energy and water consumption. Also, the implementation of the safety management is a success. Moreover, the true novelty lies in integration of the system. It shows that it is possible with promising results. Study on the system's own consumption of resources should have been studied. Virtual interfaces here are evaluated as positive impactful for its social approach towards being user friendly. Cyber side has security issues that also are needed to be addressed in the study.

B. Validation by the Conducted Survey:

The whole system model has characteristics motivated by the survey study. One of the main outcomes of the survey study is the participant's agreed upon cost range 240 US Dollar per floor. Here is the cost scenario for the proposed building floor scenario:

TABLE I. COST SCENARIO FOR EACH FLOOR

System Management	***Required Components***	***Unit***	***Unit Price (US Dollar)***	***Associated Cost (US Dollar)***
SBMS Energy Management System	Arduino	3	10	30
	NRF24L01	4	5	20
	CT	3	19	57
	PT	3	2	6
	MOC3021 Optocoupler	6	2	12
	BTA41600B	6	2	12
	Circuitry Miscellaneous (Capacitor, Vero-board, resister etc.)	1	6	6
SBMS Water Management System	Arduino	1	10	10
	G1/2" Water Flow sensor	1	7	7
SBMS Safety Management System	Arduino	1	10	10
	Sensors	2	2	4
Total				174

174 US Dollar is below the cost maximum range 240 US Dollar. This validates the system management. The cost data is collected online: techshopbd.com. Survey also ensured its market validation.

C. Discussions:

Here are the key observations in the research:

- The main intension of this research was to understand and visualize an approach to launch Internet of Things enabled smart building management product in Bangladesh market. From our conducted survey it is clear that there is a future for this market. And the simulation results are promising to the fact of its adaptability.
- During the research work, some more ideas were formulated. Here micro social network concept is introduced, which is not yet introduced in any literature or research on IoT Smart Building. Though this concept is introduced, here it was not fully explored. Also, necessary optimization couldn't be done due to time constraint.
- The TRIAC switching requires more frequency operation in the processor. With greater frequency consideration, the price of the microprocessor arises. So, optimization should have been done here in a broad way.
- The research done here only support some positive aspects of the whole system management. Total system management is not yet done
- Lowering of power factor is one of the main drawback here. Introducing capacitor bank can help to improve.
- Initially the simulation was done in **ThingSpeak**. It is an open IoT platform with MATLAB analytics. Later the data was collected and plotted on MATLAB software. The system should have its own virtual interface for control and visualization. It is not implemented yet.
- The cost is achieved within 240 US Dollar, which was a demand from the survey participants end

V. CONCLUSIONS

Bangladesh government has envisioned the Vision 2021 which targets to materialize Digital Bangladesh [20]. The four elements of Digital Bangladesh vision are human resource development, people involvement, civil services and use of information technology in business. Adopting IoT can unleash great amounts possibilities to achieve efficiency, business prospects. The study here is done, basing on a survey conducted in Dhaka City. The proposed system model can be a model for other parts of the country Bangladesh. One of the main novelty of this research lies with this. Also, the idea to make it social not only in 'Things' level but also in more humane level is a very new approach towards smart building management system. Finally, this paper proposed the idea, which paves the way for more this types of study on Bangladesh context.

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