Impact Assessment of an Intensive Base Demand Side Management Program for Telecommunication Load with Energy Storage Device in a Test Grid System Based on Bangladesh Perspective

Syed Munimus SALAM[1], *Nur MOHAMMAD*[1], *Imtiaz Akber CHOWDHURY*[2,*]

[1]Department of Electrical and Electronic Engineering, Chittagong University of Engineering & Technology Chittagong (CUET), Chattogram, Bangladesh
[2]Department of Electrical and Electronic Engineering, University of Science and Technology Chittagong (USTC), Chattogram, Bangladesh

*Corresponding Author: Imtiaz Akber CHOWDHURY (email: eee.imtiazakber@ustc.ac.bd)
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Abstract. *Power consumption by telecommunication industrial loads is increasing day by day as the user of this technology is on the rise. Telecommunication base station towers are consuming twice or more energy than in the past for the implementation of high-capacity devices to serve more users. As a result, there is an extra power requirement for the telecommunication loads which can cause an inadequate power supply and lead to the implementation of additional infrastructure in the power industry. Powering these resources will demand more energy production and introduce various types of new problems in the grid network. The impact analysis of the effect of this extra demand in a regular network system has great interest. Also, most of the base stations are equipped with a backup battery as an essential need in the third-world country grids and contribute a portion of the load demand of a power distribution system. All telecommunication industrial towers are considered under industrial load and have a special industrial tariff imposed by the power supply authority. This paper utilizes the optimal power flow method to calculate a proposed schedule base demand-side management system adopted to shift the pattern of charging batteries along with temperature control loads in the telecommunication towers and outlines an analytical study on a test power grid network. To determine the best electricity flow, generation, and locational marginal prices for each hour, an algorithm is created. Following careful evaluation of the appliance status, the constraint and condition are then applied to the load curve. This study indicates there is energy-saving and both supplier and consumer sides can minimize the operation cost.*

Keywords

Telecommunication Power, Optimal Power Flow, Power Quality, Power, MATPOWER.

1. Introduction

The world of wireless telecommunication is constantly evolving, with services being upgraded at an accelerated pace over the past few years. While telecommunication networks have traditionally been focused on optimizing communication performance, in recent times, power consumption has become a key area of interest in the planning and maintenance of wireless communication equipment. In fact, the power management has become such an important consideration that power utilities are now introducing various Demand Side Management (DSM) techniques to reduce peak consumption. Telecommunication loads are now seen as a vital part of these demand management systems, as they can have a significant impact on overall power usage.In many third-world countries, operators have to rely on battery backup systems to provide power to their infrastructure. These backup batteries can also be utilized for peak power shaving in bulk-scale consumption of a grid system, providing an additional benefit to both the telecommunication industry and the power sector.As the demand for wireless communication services continues to grow, it is likely that power management will become an even more critical consideration. As a result, the industry will need to continue to evolve and adapt to ensure that it can meet the ever-changing needs of its users while also minimizing its impact on the environment. Previously electric power vehicles and Photo-voltaic batteries are used for peak shaving purposes [1, 2]. Indeed, newly developed 5G systems will require an ample amount of extra power, contributing to conventional connectivity as well as adopting newly updated services. It is projected that by next year there will be a large number of connected equipment and devices [3]. There is an expectation that the traffic capacity in 5G networks will reach its peak. This necessitates the capacity expansion of present cellular network systems [?]. Attempting to manage this aggressive goal relying on the standards and structures of existing networks is not sustainable as it will inescapably drive an energy difficulty with severe commercial and environmental attention.

Modern Telecommunication networks are planned to maximize the capability by improving the transmit powers [4, 5]. However, this extraordinary growth of a huge number of connected gadgets requires more and more energy will result in tremendous running expenses [6, 7, 8, 9]. At present, telecommunication industry systems are responsible for 5% of the world's CO_2 emissions [10, 11], but this rate is rising as quickly as the number of associated devices. Moreover, it is predicted that 75% of the telecom sector will be fifth-generation devices by next year [12], thus assuming that this industry will become the flourishing sector to investigate the impact of extra energy consumption.

Though new devices will double to triple power consumption for telco operators, Unicom's research institute predicts overall 5G power consumption will be higher than three terms the level of the 4G consumption [13, 14, 15]. The average 5G site has energy requirements of above 11.5 kilowatts, up approximately 70% from a base station deploying a mix of 2 or 3, or 4G radios [?, 16].

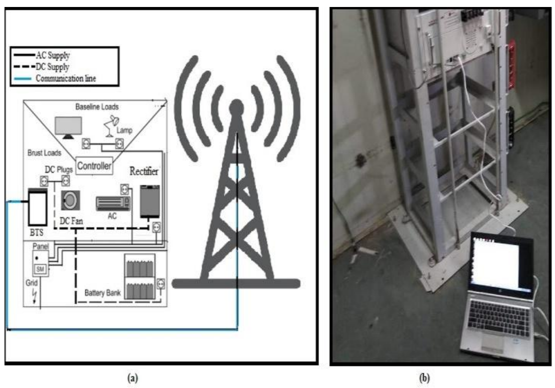

Fig. 1: Load division of a telecom load.

Also, as per the United States Data Center Energy Usage Report, Datacenter and infrastructure-related consumption will be increased with new capacity implementation. It will increase up to 4% of total consumption from 2% and above [17]. An overview of a practical load division is represented in Fig. 1.

According to a report by the U.S. Department of Energy, data centers in the United States consumed approximately 100 billion kilowatt-hours (kWh) of electricity in 2020, representing about 2.3% of the country's total electricity consumption. This is a significant increase from previous years and is expected to continue growing in the future. Efforts have been made to reduce energy consumption in data centers, such as the adoption of energy-efficient technologies and the use of renewable energy sources. However, as the demand for data continues to increase, it remains a significant challenge to minimize the environmental impact of these facilities while maintaining their critical functions.

Finally, data center energy usage in the world is a significant concern, and efforts are being made to reduce their energy consumption and environmental impact. However, the increasing demand for data and digital services means that this will remain an ongoing challenge for the foreseeable future.

2. System Model

Considering a reliable and efficient energy management system, for some user-defined load combinations including residential and telecom loads, two main approaches are followed shown in Fig. 2. Either top-down approaches or bottom-up approaches can be taken into consideration for the calculation of loads to obtain the consumption of the whole area or particular base stations in the different node bus. To find out the energy consumption every hour wise, historical data is considered for different appliances for a full-day period. As for the power consumption for telecom equipment, the number of telecom equipment is counted several times as per the traffic requirement. Mobile interfaces are one of the major power consumers considering the total power consumption. Analyzing the recent research, the estimations of energy demand do not expose the accurate consumption requirement [9, 18, ?, 19]. There are few investigations where the energy consumption of telco services provided by systems has been studied [20, 21]. The typical wireless network can be viewed as composed of three different sections

I. I. the Mobile Switching Center (MSC), which takes care of switching and interface to the fixed network (for 5G it will change into a data center);

II. II. Radio Base Station (RBS), which takes care of the frequency interface between the network and mobile terminals (for 5G it will change into RAN);

III. Mobile terminals, which are the subscriber's part, are normally limited to the handheld device.

1. 1. It is estimated that the overall operator's operating expenses mainly depend upon base station power consumption. To find out the consumption in Bangladesh a survey was conducted on telco operators in Chattagram city and the suburb area.

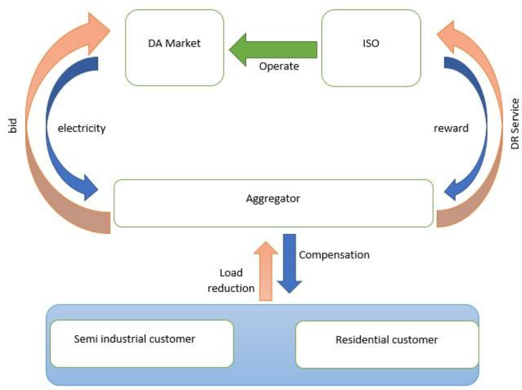

Fig. 2: Market structure considered.

This study considered both telecom and residential loads by bottom-up approaches to get the consumption of a distribution area. Also, each domestic client is estimated to be an independent individual who can control appliances through the home management controller. Similarly, telecommunication base station loads can be controlled by the central office through a control system. For easy calculation, the appliances are further classified into two types-

1) Baseline loads: the loads that are always in use;

2) Burst loads: the loads that can be shifted with time as per customer need.

Although, the feasibility of this type of load and their demand response has not essentially been considered due to the tiny part of these scattered base stations is not so large to count for the operator's required threshold. Although the total share of telecom load will be increased in power operation, its growing influence on the overall demand, there is an opportunity to consider this on DSM.

As a result, aggregators can consider the possibility of these loads competing in price-concentrated or incentive offer-based DR schemes.

3. Proposed Framework for Simulation

A digital set-up was established for template data acquisition where the obtained data was collected in a server arrangement and finally, an investigation was done with the stored data [22]. To get a better result from the simulation, firstly, we have to define an aggregator-centered hierarchical market arrangement. Details of the market structure have been represented in Fig. 3. This arrangement has already been adopted in many research projects [23, 24] and several DSM schemes [25, 26]. The details of the information flow and electricity selling process in the market are shown by the auxiliary arrows in the figure. Here the independent service operator (ISO) operates a day ahead (DA) market to sell power to aggregators. Aggregator proposes a demand response (DR) package to the ISO and gets a reward for this. On the other hand, this aggregator regularly offers purchase proposals in the DA market for required power. This purchased power would be delivered to the demand side regularly. These aggregators offer some incentives to the customers to get rewards by managing their electricity load as per aggregator requirements. The energy saving as a result of DSM for specific incentive offers proposed by the aggregator is considered for the pick hour. Thus, it is possible to recognize the possibility to calculate and represent the responsiveness load consumption by telecommunication load. Considering $N_{TA} = \pi r^2$ samples in a capture period, the acquired samples are sequences of length N_T as shown in (1) and (2).

$$v_{acq} = \{v_{acq}(n)\}_{n=1}^{N_T} \tag{1}$$

$$i_{acq} = \{i_{acq}(n)\}_{n=1}^{N_T} \tag{2}$$

The energy consumption for any load number (like rectifier, BTS, Lighting, and household) can be obtained from

$$P_{load} = \frac{1}{N}\sum_{n=1}^{N} v_{acq}(n) * i_{acq}(n) \tag{3}$$

For any mixed combination, the power can be calculated as

$$P_{mixedload}\frac{1}{N}\sum_{n\ =1}^{N} v_{acq}(n) * \{n_{TCL} * i_{TCL}(n) + n_{SL} * i_{SL}(n) + n_{BL} * i_{BL}(n)\} \tag{4}$$

where n_{TCL}, n_{SL}, and n_{BL} express the number of TCL, SL or BL appliances and i_{TCL}, i_{SL}, and i_{BL} denote the current consumption for TCL, SL or BL appliances. For TCL and SL we count,

$$n_{TCL} = \begin{cases} 0 \quad \text{if temp} \leq 26°C \\ .5 * n_{tcl} \quad \text{if } 26°C \leq temp \leq 30°C \\ Otherwise \end{cases} \tag{5}$$

All base stations will run one air conditioner (AC) unit when the temperature is within 26 to 30 degrees Celsius and run two AC units for temperatures over 30 degrees.

And $n_{SL} =$

$$\begin{cases} n_{sl} \quad \text{if time} \leq \text{Lower Threshold (LT)} \\ 0 \quad \text{if LT} \leq \text{temp} \leq \text{Upper Threshold (UT)} \\ 3n_{sl} \quad \text{if LT} \leq \text{temp} \leq \text{UT + 2hr} \end{cases} \tag{6}$$

Here the equalizing charging current for a rectifier (SL for telecommunication load) would be active for two hours as per equipment setting rectifier will draw three times more current after shifting.

4. Process of Cost Calculation for Different Types Telco Loads with Other Load Combination and DSM Calculation

This paper analyzes the system cost for a six-bus test system considering a model mentioned in [27]. The system modification consists of calculated load demand for different day hours. Five generations situated in alternative node buses from different IPP are serving the load requirement. Here Stadium (Industry), Hillview (Suburb), and Khulsi (city) feeders, the appliances considered after surveying a portion of the city and suburb area where different load combinations for a bottom-up approach for daylong conditions. To make the analysis simple, the required considerations are noted below:

1. A balanced three-phase system is assumed where loads are equally distributed with each phase arrangement.
2. All the computations were considered with a single-phase arrangement, thus results were obtained from the representation of one phase, assuming the same results for the other two phases.

All output parameters are summarized to find out the load demand for nodal-level load-serving entities (LSE). Telecom operators run most of the telecom equipment with a DC voltage system and DC backup is available to most of the operating towers. During the pick load hour, the 60% to 70% load consumption can be shifted by running the system with battery backup. It will reduce power consumption and also electricity bills as the pick-hour billing is higher than that of the off-peak hour. Reducing the same amount of peak demand and increasing it during the off-peak hour will help pick load shaving.

To find out the overall system output, a MATLAB-based program is developed to optimal power flow solution for every hour in. The flow chart shown in figure Fig. 3 describing the condition that applied to the telco load after counting all appliances. As there are three demand nodes available in the six bus system the number of node 'n' will be three and the input DR intensive start time can be denoted as T_S^K and the end time can be denoted as T_E^K where k represents the intensive sequence of the day.

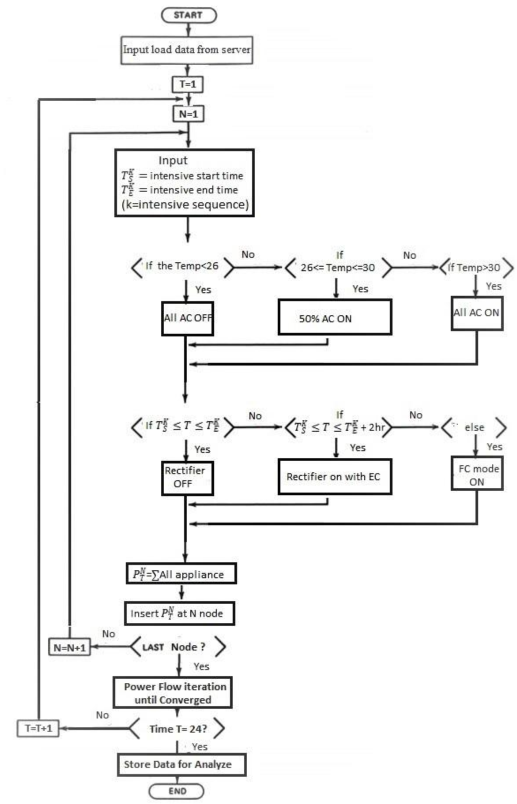

Fig. 3: MATLAB Program Flow Chart.

Any TCL load like Air cooler operation can be counted with three possible states with respect to temperature change. For below 26 degree Celsius no AC is in operation while one AC runs for the environmental temperature within 26 to 30 degree Celsius and two AC run for higher temperatures. Power consumption of a rectifier load with power interruption was surveyed for different time duration and stored for future power calculation. For any intensive period offered for telco, sites shift the SL of the base station sites and SL is kept powered off and run by ESS backup. When the intensive offered period ends, these rectifiers start to run with grid power and extra power required to charge the backup bat-

Tab. 1: System Parameter of Six Bus System.

Generator Data						
Gen	Pmax	Pmin	Qmax	Qmin	C2	C1
	(MW)	(MW)	(MVAR)	(MVAR)	($/MW)^2	($/MW)^2
1_1	25	0	70	-70	0.0005	8.5
1_2	6.75	0	50	-50	0.0005	12
2_3	15	0	200	-200	0.0005	9
3_4	4	0	40	-40	0.0005	14.5
4_5	20	0	40	-40	0.0005	9.5
Bus load Data						
Bus	P(MW)	Q(MVAR)	Vmax(p.u)	Vmin(p.u)		
1	0	0	1.1	0.9		
2	0	0	1.1	0.9		
3	0	0	1.1	0.9		
4	Demand	Demand	1.1	0.9		
5	Demand	Demand	1.1	0.9		
6	Demand	Demand	1.1	0.9		

Tab. 2: OPF Solution for Load Variation with Change in Participation No.

DSM in % Inten-sive	Costly Generator Consumption	Energy Saving (MW)	Highest LMP offered ($)	Lowest LMP Offered ($)
0	0.098	0	14.5736	12
5	0.0557	-0.0107	14.5735	12
15	0.0484	0.0064	14.5716	12
25	0.0408	0.0236	14.5713	12
35	0.0334	0.0407	14.5709	12
45	0.026	0.0579	14.5704	12
55	0.0185	0.075	14.5696	12
65	0.0123	0.0922	14.5684	12
75	0.0133	0.1094	14.5725	12
85	0.016	0.1265	14.5714	12
95	0.0204	0.1437	13.6935	12

tery shown in equations (5),(6). Finally, Power flow iteration is done until the system converges and stored data is used to develop the demand curve.

5. Result and Analysis

In the graphical analysis, it is observed that the overall consumption changed with time. There are evening and morning pick hours that can be pointed out when the overall consumption increases for every node. These pick demand hours can be analyzed by load duration curves where the varying load of a different node bus is counted with time. If the DSM is applied for the highest peak demand hour or more and intensive is offered by the aggregator to the consumer for reducing the non-essential loads of telecom infrastructure during the peak hour, with load reduction for low load consumption, generators have a reduced production requirement.

For analysis purposes, this assumption is done for the six bus solutions listed in the following Tab. 1. There are five generators that are considered for four generator buses. All loads were calculated as per the consideration listed in Tab 1. Also, generators with higher fuel and production costs can be kept at rest or low production lines and the overall cost will be reduced. To consider such a situation six bus systems are considered where the fifth number generator with higher production cost will serve the picked load during peak demand hour. Using Tab 2, for the first case study, a usual demand curve is considered for typical load consumption in a residential area. As per observation, the morning peak hour starts at 8 am and ends at

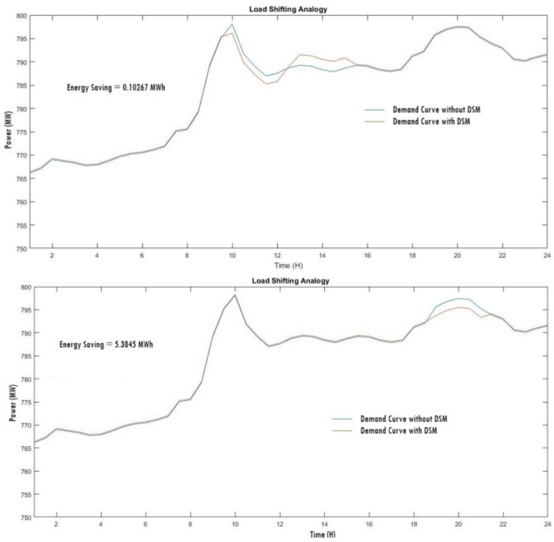

Fig. 4: Time shifting analogy.

noon, and the evening peak begins at 18.30 and stops at 21.00 sharply. In such circumstances, the aggregator offered a regular intensive on energy consumption bill to reduce peak demand for telecom customers. Most of the telecom base stations have a rectifier with battery backup. So, they avail the offer for their operation cost reduction. This paper analyzes the impact of utilizing the intensive offer by telecom loads. This peak demand reduction can be gained by shutting down the telecom rectifier and running the equipment by dc backup system. As a result, the charging load shifted to the next quarter.

From the Tab. 3 summary, it is reflected that for local marginal load (LMP) consideration, the highest LMP required for the intensive offered period will be reduced gradually if the DSM participation in telecom sites increases. Similarly, overall energy saving will be increased by this DSM policy applied but for low participation, the overall consumption may increase by a little amount. Load shifting to any suitable time that even occurred by a realistic proportion of loads would decrease the overall cost per hour. The power consumption of the generator running with costly fuel is declining with shifting load support increasing. Though the optimum value is remaining in between 65 to 75 load participation with the intensive offer. Analyzing, it is easily understandable that LMP values are declining with participation increasing but the LMP value sometimes increases as an aftereffect of the DSM approach. The reason is the large power consumption required for the charging load can be somehow reduced by this peak-shaving technique will require a notable amount of charging load. In the second case study, the paper focuses on the impact of the time-shifting of DSM with respect to peak hour consumption for the considered demand data analysis. At first, DSM consideration was taken for a two-hour duration. As the evening peak and morning peak demand hour duration almost remain between two hours, there is a positive impact and LMP lies between 14.5696 to 12 dollars which is the lowest cost among the LMP values. If the DSM offered period is lower than the peak demand hour or the major participant of the DSM offer starts to consume power in between the peak demand hour the scenario may change. It is obvious that the costly generator production increases with the decrease in DSM time length. As shown in the Fig. 4 DSM availed in the first hour will cause a new pick rise at the next hour due to the charging current added with the picked load. On the other hand, DSM availed during the last part of the peak demand hour has no such impact as there is a downslope for reducing load consumption. In Tab. 3 the production of costly generators increases for DSM availed or offered for the very first hour of the peak demand period. From the energy-saving perspective, DSM time decrease causes a decrease in energy-saving value. Also, saving depends on the intensive period offered and availed by the target customer for a smaller period than the peak-demand hour.

6. Conclusion

This study represents the AC OPF calculation with six bus arrangements. Here the demand loads are varying due to the application of DSM policy on the consumer side. This study implies that a considerable proportion of telecommunication consumers offered to participate in the DSM program to make a notable contribution to the daily demand curve of power systems and improve energy efficiency. A large

Tab. 3: OPF Solutions for Load Variation with Time Shift

DSM in hour	Costly generator consumption (MW)	Energy Saving (MW)	Highest LMP in dollar	Lowest LMP in dollar
0	0.098	0	14.5736	12
2	0.0185	0.075	14.5696	12
1.5	0.0911	0.00154	14.5737	12
1 (1st hour)	0.1602	0.0049	14.5738	12
1 (Last Hour)	0.1052	0.0078	14.5736	12

part of the survey implies that telecommunication sites are running with a backup battery system for the service reliability of telecommunication appliances, which can be utilized for load-shifting purposes. In this test bus grid arrangement, when DSM participants reduce below 15 percent shows a negative value toward energy-saving possibility. Otherwise, it would be beneficial to implement strategies to establish DSM with telecommunication load shifting with ESS backup from all perspectives. As the telecom loads are already maintained with sufficient battery backup, no extra costing required to implement this policy. Therefore, there are no such technical barriers related to load-shifting for telecommunication loads. In the proposed system, with the addition of the DSM approach, it is possible to reduce costly power production and also the customer as the LMP reduces in almost every nodal bus. Additionally, policymakers of the aggregator should pay attention to the time duration of specific offers much matches the peak demand hour and most of the target customers should be included to get demand flexibility. Such this study formulated DSM of the battery-operated ESS Loads that represent near about 5 to 6 percent offload shifting possibility. In conclusion, this analysis introduces a new approach for load shifting techniques to improve the system flexibility, as well as the cost of the DSM technique, which is applied for pick shaving the load with respect to other loads applied to a node. The result indicates that a sufficient power reduction can be obtained by shifting the temperature control load and rectifier battery charging load, and thus the customer can get the benefit of low-cost power consumption.

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About Authors

Syed Munimus SALAM received the B.S. degree in Electrical & Electronic Engineering from Chittagong University of Engineering and Technology, Bangladesh in 2004 and M.S. degree in Electronic Engineering from Bangladesh University of Engineering and Technology, Bangladesh in 2010. He is currently a faculty member of the Department of Electrical and Electronic Engineering at the University of Science and Technology Chittagong (USTC), Chattogram, Bangladesh. His research interest includes Power Grid, Demand Side Management, and wireless-powered communication with energy harvesting and the Internet of things.

Prof. Dr. Nur MOHAMMAD (St. M 2015, with IEEE) received Ph.D. (2018) degree from Queensland University of Technology (QUT). He received the B.Sc. (in 2008) and M.Sc. (2014), both the degree in electrical and electronic engineering. He has been working with the Chittagong University of Engineering and Technology (CUET) as an academic faculty since 2009. His current research interests include an electricity market model for a future smart grid, renewable energy integration, frequency and voltage regulation, power system economics, demand-side management, energy storage management, auction-based demand response mechanism design, bi-level optimization, network optimization, and game theory.

Imtiaz Akber CHOWDHURY received the B.S. degree in Electronic & Telecommunication Engineering from International Islamic University Chittagong, Bangladesh in 2014 and M.S. degree in Electronic Engineering from Kyung Hee University, Yongin, South Korea in 2020. He is currently a faculty member of the Department of Electrical and Electronic Engineering at the University of Science and Technology Chittagong (USTC), Chattogram, Bangladesh. His research interest includes unmanned aerial vehicle communication, cooperative communication, and wireless-powered communication with energy harvesting and the Internet of things.

