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Artificial Intelligence Driven Mechanism for Edge Computing based Industrial Applications

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***Abstract*—Due to various limitations i.e., computational complexity and more delay in cloud computing is overtaken by edge computing for efficient and fair resource allocation such as, power and battery lifetime in internet of things (IoT) based industrial applications. In the meantime intelligent and accurate resource management by artificial intelligence (AI) has become the center of attention especially in industrial applications. With the coordination of AI at the edge will remarkably enhance the range and computational speed of IoT based devices in industries. But the challenging issue in these power hungry, short battery lifetime and delay intolerant portable devices is inappropriate and inefficient classical trends of fair resource allotment. Also, it is interpreted through extensive industrial data sets that dynamic wireless channel could not be supported by the typical power saving and battery lifetime techniques for example, predictive transmission power control (PTPC) and Baseline. Thus, this paper proposes i) a forward central dynamic and available approach (FCDAA) by adapting the running time of sensing and transmission processes in IoT-based portable devices ii) a system-level battery model by evaluating the energy dissipation in IoT devices iii) a data reliability model for edge artificial intelligence based IoT devices over hybird TPC and duty-cycle network. Two important cases for instance, static (i.e.,product processing) and dynamic (i.e., vibration and fault diagnosis) are introduced for proper monitoring of industrial platform. Experimental test-bed reveals that proposed FCDAA enhances energy efficiency and battery lifetime at acceptable reliability (~0.95) by appropriately tuning duty-cycle and TPC unlike conventional methods.**

***Index Terms*—Industrial IoT, Edge Computing, AI, Duty-cycle, Mobile devices , PTPC, FCDAA, Battery Model**

I. INTRODUCTION

Industrial revolution has caught the attention of IoT-enabled smart world by integrating edge AI mechanism with mobile technologies while transmitting multimedia (i.e., text, images and video, etc) content. An integration of the heterogeneous networks and wearable devices on the one hand can facilitate the each and every corner of the world, while on the other-hand several challenges are faced by customers or users. With the advancement in mobile devices industrial sector is revolutionized at large extent. At present the AI driven edge computing mechanism for industrial applications is very vital for the entire world to solve most the relevant issues at global level.

Main challenging problem which most of the industrial applications are facing is the resource-constrained (i.e., power hungry and short battery lifetime) nature of the IoT enabled portable devices in the integrated platform. Artifiical Intelligence (AI) has become the center of attention to several applications [1]. In industrial platforms IoT devices continuously monitor event triggered information which is further transmitted to a remote server, so apprehending monitoring of the industrial outcome [3]. However, for providing ease and comfort through IoT enabled portable devices, there are problems high energy drain, shorter battery lifetime and complex computational process [4,5]. There is a requirement for conventional batteries to be regularly recharged/replaced in IoT based sensor devices. One of the examples is that in the fault diagnosis and recovery sensors, it is very cumbersome to frequently change their batteries. Therefore, energy drain optimization and battery lifetime extension in IoT based sensor devices are the challenging task to be focused[1]. Fig.1, shows the proposed AI-enabled framework for industrial applicaations. It comprises four sections with different functionaliteis such as, adaptive edge node, adaptive network node, adaptive application node and service node. First, Edge node which contains six key blocks (power controller, dudy-cycle optimizer, reliability optimizer, sensors & actuators, microcontroller & ADC, and connectors) collects data, stores in cloud, process, analysis and monitors with the help of edge intelligence which is based on cognotive knowledge of the entire industrial mechanism. Second, Adaptive network node gets information from adaptive node and manages that data with router, repeater, satellite system, access point, router and wireless local area networks. Third, adaptive application node gets information from upper layers by hnadling the fault diagnosis and monitoring of the entire platform to the last service node. Forth, service node deals with the duty-cycle and energy optimization in the overall industrial system.Currently, most of the researchers show their concerns over the energy depletion in edge AI based IoT devices due to power hungry, tiny size, and poor performance of conventional approaches [7][6][1]. Nevertheless, few researchers comprehend optimization of duty-cycle and energy drain in industrial sector via energy harvesting. In general, energy in the IoT based industrial platforms is scavenged by different methods such as, wireless power transfer, wind-turbines, and vibration etc [1][8].But due to their unsteady, random results and inappropriate load cannot be used for real-time industrial applications[9][10]. Wireless power transfer benfits to industrial application by scavenging energy from wind, RF sources [11]. Also, the simultaneous wireless information and power transfer (SWIPT) is not the viable solution to fix the issues of fair resource allocation and energy drain optimization. It is discussed and examined by [12][13] that wireless power transfer (WPT) can be suitable option for the current industrial applications due to emerging wireless technological trends and practices. Actually,

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the miniaturized and resource-confined nature of the IoT-based edge AI devices results in a significant proportion of energy dissipation during sensing and transmission phases, and it is apparently impossible to neglect energy depletion of these tasks. Traditional sensor networks cannot be re-energized due to static node distribution mechanism and battery's empty level, thus huge amendment is needed to bring these up to current needs of the industrial world [15]. Thus, to meet the required needs of each application, a hybird adaptive TPC and duty-cycle has become potential candidate for AI-based edge computing in industrial applications. Our proposed FCDAA optimizes the power, extedn the battery lifetime with high reliability in AI based edge computing industrial application for the first time as per author's knowledge. The proposed FCDAA tunes transmission power level and duty-cycle of IoT devices in industrial applications by adopting static (product processing) and dynamic (vibration and fault diagnosis) platform at acceptable reliability or packet loss ratio (PLR).

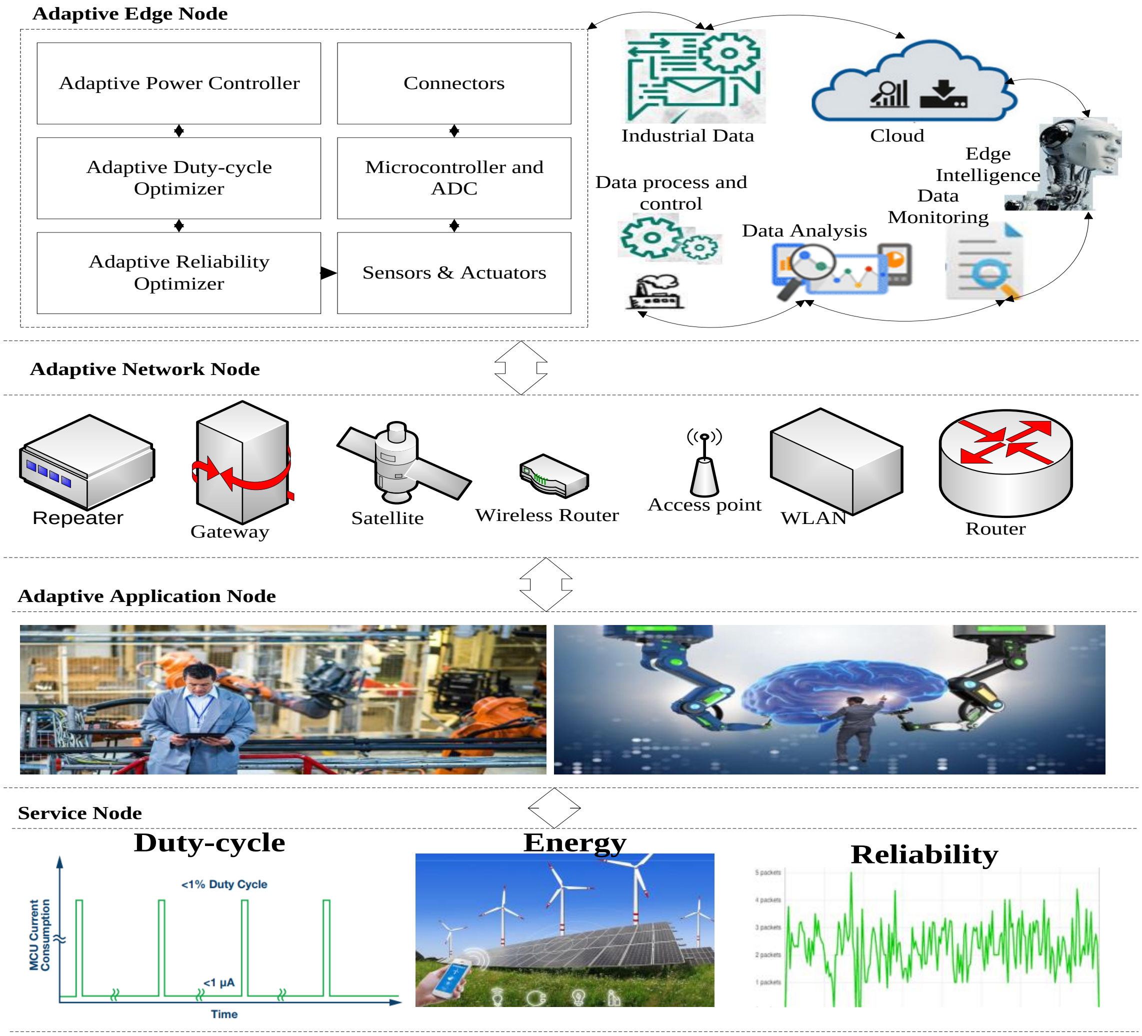

Fig. 1. Proposed Architecture of AI based Edge computing platform for Industrial Applications

The contribution of this paper is three-fold.

- First, a foraward central dynamic and avilable approach (FCDAA) is proposed for managing the execution time of sensing and transmission tasks in AI-based IoT devices for industrial applications.
- Second, system-level battery model of edge AI-enabled IoT devices for industrial applications is proposed by examining the duty-cycle and energy optimization.
- Third, data reliability model of IoT based hand-held devices over hybird TPC and duty-cycle network is proposed to effectively monitor the industrial IoT.

The rest of the paper is arranged as follows. Section 2 rigorously reviews the existing works. Forward Central Dynamic and Available Approach and battery model are developed in Section 3. Data reliability model is proposed for hybird TPC and duty-cycle industrial networks in section 4. Experimental test-bed is developed in Section 5. Section 6 concludes the paper.

II. EXISTING WORKS

This section provides the rigorous literature about duty-cycle based techniques, and power-aware algorithms, architectures, reliability models for AI-based industrial applications.

TABLE I. RELATED WORK

Ref. No	Applications	Proposed Solution	Merits	Demerits
[1,3,4]	AI, Energy Energy optimization, delay	TPC based	Energy and Charge efficient	Complex and inefficient
[2,5,8]	IoT signal for industrial system	TPC, Channel and battery-aware	Duty-cycle, data rate	High energy and battery drain during media transmission
[6,7]	Edge and AI based industrial platforms	Cloud and battery enabled	Fairy and battery efficient	Less power-aware and battery-efficient
[9,10]	Energy-aware IoT for Industrial platform	Frameworks and protocols	Extensive survey for AI-based industrial application	Not focused on Industrial applications
[11,12]	AI based edge computing and WSN	Energy-aware and routing protocols	Energy optimization and efficient routing	Complex and less battery-efficient
[13]	WPT and Industrial WSN	Energy harvesting and duty-cycle enabled	Battery and energy-aware	Inappropriate for industrial platform
[14]	IIoT , AI, Adaptive methods	QoS optimization based	Efficient QoS management	Less Battery and energy - efficient for Industrial IoT
[15]	Machine Learning and Cellular networks	TPC and relay selection based	Novel Architecture and resource allocation method	High battery and energy drain in industrial system
[16]	WSN and communication systems	TPC and resource allocation	Energy optimization in wireless and sensor networks	Complex and less reliable for dynamic industrial platform
[17]	Industrial IoT, WSN	Energy and battery-based frameworks and method	Efficient resource allocation	Complex and less battery-aware for Industrial services
[18]	WPT and Radio networks	TPC and radio-aware	Intelligent resource monitoring in radio networks	Unsuitable for IIoT system
[19]	Future Networks, WSN	QoS and Energy Scavenging	Novel energy and QoS efficient	Complex and less reliable for Industrial system
[20]	WPT for IIoT	TPC and QoS-aware framework	Detailed survey	Not focus at joint duty-cycle and TPC
[21]	IoT for Edge computing	Energy and battery-oriented	Novel Physical layer and framework for industrial applications	Complex, less reliable without duty cycle
[22]	Industrial platforms	Fuzzy based secure	Secure home monitoring	High energy drain
[23]	Energy-aware and secure WSN	TPC and battery-based	Efficient media transmission	More battery drain
[24]	IoT based edge platform	Framework and battery-aware	Efficient lifecycle management	Less energy saving
[25]	QoS-aware IIoT and CPS	Optimal resource allocation	QoS monitoring and management	More energy and battery drain
[26]	Ubiquitous and Smart IIoT	TPC based and framework	Novel process monitoring algorithm and framework	More battery drain
[27]	AI, QoS, IoT,	Routing protocols and framework	Routing and battery-based	More energy dissipation
[28]	Power allocation in Industrial systems	AI-aware	Novel Framework and methods	High energy drain

Because of the high inspiration from every domain sensor networks have caught the attention in the industrial corner to examine and observe the processing, monitoring and outcome. But these heterogeneous networks are facing the critical challenges due to the power hungry and limited battery lifetime, hence are not offering accurate and timely services at economical level. Energy harvesting has been employed to increase the lifetime of nodes as a substitute to supplement batteries. Hybird TPC and duty-cycle based approach plays the critical role for energy-aware industrial system with distinct methods. For example, modulation level control, duty-cycle optimization, network scheduling at physical, MAC and network layers accordingly. Energy neutral operation (ENO) is widely accepted mechanism during harvesting the energy and manages the power by typically adjusting the duty-cycle or wake-up duration of the sensor nodes.

In this paper, for the first time a FCDAA and data reliability models are proposed for AI-based industrial application over hybird TPC and duty-cycle network to save energy. TPC levels and duty-cycle i.e., wake-up and sleep periods of IoT based devices are adapted while taking into account the deviations of the wireless channel i.e., static (product processing) and dynamic (vibration and fault diagnosis) cases.

III. PROPOSED FORWARD CENTRAL DYNAMIC AND AVAILABLE APPROACH

This section describes in detail the two key parts first proposed FCDAA and second system level battery model by integrating both TPC and duty-cycle for AI driven industrial applications. One of the vital energy and battery lifecycle management methods in IoT based industrial applications is presented in [14]. The key purpose of the proposed FCDAA is to extend the battery lifetime and save the power in AI based edge computing platforms for industrial application. Besides, the transmission power control and duty-cycle entities of the IoT based portable devices are optimized by properly following energy neutral operation during sensing, processing and transmission of industrial data. Assume that, $\chi_{tx}(TP)$ and χ_{FC} are the battery charge depletion at adopted power levels and CPU's extra energy drain by forward central consequently as depicted in Fig. 2. Besides, the duty-cycle management mechanism is presented in Fig. 3. In duty-cycle analysis harvesting energy from access point to nodes is playing remarkable role in examining the overall network performance.

When harvesting energy rate is greater than the threshold amount ($\kappa \geq \kappa_{th}$) than next active period can be predicted by using (4) and Fig. 2.

```
Initialization:
 Define: $TP, \chi_{tx}(TP), \chi_{DAA}, C_{leak}, S, n, \sigma$
 Set: $E(t) = \sum_{i=1}^{S}\left(E_{sen_i}(b) + E_{tx_i}(b, d_{ij})\right)$, $DC_S(t) = \sum_{i=1}^{S}[\gamma - (E + C_{leak})] \times T_{ON}$
 $\mathrm{Re}\,liability = \frac{\sum_{i=1}^{n}(RSSI_{th} - TP) + \sum_{i=1}^{n}(RSSI_{th} + TP)}{n \times \sigma} \times DC$
Event on $E(t), DC_s(t), \mathrm{Re}\,liability(t)$
  for $i \leftarrow 1$ to $S$ do
      compute $E(t) = \sum_{i=1}^{S}\left(E_{sen_i}(b) + E_{tx_i}(b, d_{ij})\right)$, based on Eq.(3)
      computer $DC_S(t) = \sum_{i=1}^{S}[\gamma - (E + C_{leak})] \times T_{ON}$, based on Eq.(4)
  end
  for $j \leftarrow 1$ to $n$ do
      compute $\mathrm{Re}\,liability = \frac{\sum_{j=1}^{n}(RSSI_{th} - TP) + \sum_{i=1}^{n}(RSSI_{th} + TP)}{n \times \sigma} \times DC$, based on Eqs. (5) and (6)
  end
  If $(\kappa \geq \kappa_{th}) \& \& (T_{FC} = T_{tx})$
      compute $T_{tx}(t) = \left\lceil \frac{\chi_{sense}(TP) + \chi_{tx}(TP) + \chi_{DAA}}{\kappa - (\gamma_{sense} + \gamma_{tx} + C_{leak})} \right\rceil$
  else
      update $T_{tx}(t) + n$
  end
end
```

Fig.2. Proposed forward central dynamic and available approach

Otherwise, negative energy state will be obtained by proposed FCDAA when sufficient energy is not harvested. Besides, FCDAA's key functionality is to optimize the sleeping time, transmission power level at zero-energy interval time duration. Also, a deviation factor (σ) is introduced for achieving the targeted threshold by rectifying the problem during battery lifetime maximization. A transmission time is then calculated and be suitable for full-cycle as in Fig. 3. The running time of the forward central control (T_{FC}) is adopted according to the next transmission task and n accordingly. The tradeoff between forward central control, CPU's overhead bits and sensitivity will be established by tuning associated parameters [14]. In the last node will be in sleep mode before the FCDAA's new assignment with active duration (T_{ON}) appears. Energy drain can be rectified with the use of duty-cycle and dynamic transmission power. With efficient and accurate energy scavenging mechanism less transmission power is used with acceptable PLR. It is analyzed that T_{ON} is non-linearly related to battery lifetime. The proposed system level battery model comprises two periodic functions such as, sensing and transmission in industrial applications. In each task IoT device's active time is represented by T_{ON} . Various tasks lies in the active duration such as, processing, sensing and transmission, while more energy is saved and hence less battery charge consumed during inactive i.e., sleep mode. Battery charge dssipation (χ) and T_{ON} of the nodes provides Current (χ_i) value as presented in (1).

$$\gamma_i = \frac{\chi_i}{T_{ON}} \tag{1}$$

Average Current value is obtained either by monitoring task load (χ_i) or execution time (T_{ON}). Hence, duty-cycle of IoT based sensor devices S is given in (2) and Fig. 3.

$$DC_S = \frac{T_{ON}}{T_{ON} + T_{OFF}} \tag{2}$$

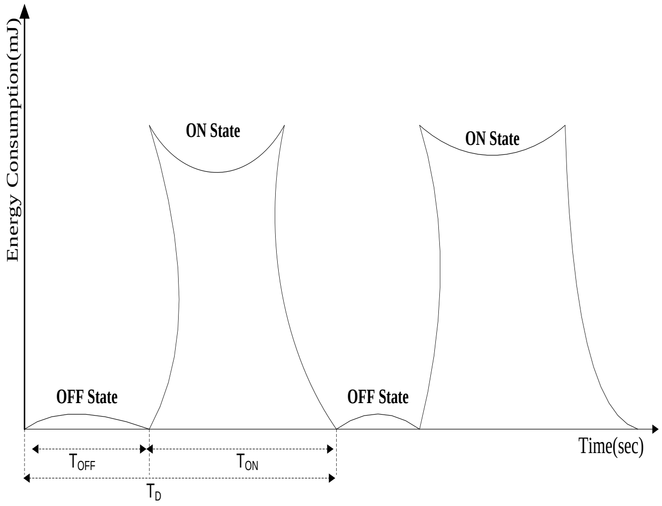

Fig.3. Dutycycle management in IoT devices for Industrial Applications

Whereby, T_{ON} , and T_{OFF} are the active and sleep time of nodes acordingly. The energy deletion of sensing and transmission tasks of IoT devices in industrial applications is analysed by operation of transmitter and base station. Industrial data is measured, recorded and communicated to the intended destination with the help of the sensor eanbled devices, but the key problem is their power hungry and resource-constrained nature. To remedy these issues the duty-cycle of the transciever must be properly managed and monitored. For instance, the time-period of sensor 'i' where $i = 1, 2, ..., S$ is computed merely during the sensing and transmission tasks. Energy dissipation of former and later tasks while transmitting b bits at distance d_{ij} for sensor j is $E_{sen_i}(b)$ and $E_{tx_i}(b, d_{ij})$ consequently. So battery charge level or state of charge (SoC) of these miniaturized sensor nodes is measured according to the energy (sensing and transmission) depletion level as in eq. (4). Besides, SoC heavily depends upon the current consumption during sensing (χ_{sense}) and transmission (χ_{tx}) respectively and the energy scavenging (β) entities. Battery SoC for the next active slot (T_{ON}) can be predicted according to the (4).

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$$E = \sum_{i=1}^{S}\left(E_{sen_i}(b) + E_{tx_i}(b, d_{ij})\right) \quad (3)$$

$$BatteryLifetime(DC_S) = \sum_{i=1}^{S}\left[\gamma - \left(E + C_{leak}\right)\right] \times T_{ON} \quad (4)$$

IV. DATA RELIABILITY MODEL FOR HYBIRD TPC AND DUTY-CYCLE NETWORKS

A novel data reliability model for the AI-based industrial applications over hybird TPC and duty-cycle network is proposed. In these networks, received signal strength indicator (RSSI) and packet loss ratio (PLR) are the key performance indicators for examining the entire system.

$$\mathrm{Re}\,liability = \begin{cases} RSSI_{th} - 1, TPC = \pm 1 \\ RSSI_{i-1} \le RSSI_{th}, TPC = 1 \\ RSSI_{i-1} \ge RSSI_{th}, TPC = -1 \end{cases} \quad (5)$$

$$\mathrm{Re}\,liability = \frac{\sum_{i=1}^{n}(RSSI_{th} - TP) + \sum_{i=1}^{n}(RSSI_{th} + TP)}{n \times \sigma} \times DC \quad (6)$$

Fig. 4 reveals the framework of the reliability optimization in the AI based edge comuting platform for indusrial application by adopting case1 (static:product processing) and case2 (dynamic:vibration and fault diagnosis) self-adaptive mechanisms. In addition, TPC and RSSI level are taken at the physical layer while duty-cycle is considered at the MAC layer. TPC is adapted according to the variation in the wireless channel which impacts a lot on the RSSI level, PLR, and hence the reliability. The case 1 and case 2 are given as the inputs to the wireless channel, which feeds to the adaptive TPC techniques from where signal's level is examined and then transmission is started to monitor and manage the power by adopting the IEEE 802.15.4. Besides, Case 1 and Case 2 in Fig.4 are very vital for accuretly analyzing the behavior of the IoT-based portable devices in industrial platform..Relationship between modulation level, duty-cycle and energy drain is drawn in Fig.5 (a) and (b) accordingly for proposed FCDAA, PTPC and Baseline by adopting AI based edge computing mechanism in industrial applications. Modulation level or data rate varies with respect to the requirement of sensors and static, dynamic industrial scenarios then there will be change in the energy dissipation level. Increase of data rate makes the power draina and battery lifetime in IoT based portable devices for industrial applications as a critical challenge. In industrial applications large data rate consumes significant amount of power in both processing and transmission phases as shown in Table III. While Fig. 5 (b), shows the interconnection between the duty-cycle and the energy drain for the proposed FCDAA and the traditional methods i.e., Baseline and PTPC. Fig. 6 (a) reveals the trade-off between the time and the standard deviation of proposed FCDAA, and conventional i.e., PTPC and Baseline methods. It is observed that there is more deviation in the later than the former due to unstable nature of the wireless channel which affects a lot to the overall performance of the industrial environment . Fig. 6 (b) reveals the relationship between sensor nodes and the energy drain for the proposed FCDAA and the conventional i.e. PTPC and Baseline. It is examined that as the number of sensor nodes are increasing the energy dissipation increases too, which is higher for the traditional methods and less for the proposed FCDAA. Besides, it is analyzed that network congestion is linearly related to the delay and hence the energy drain in the traditional techniques unlike the proposed FCDAA.

V. EXPERIMENTAL RESULTS AND DISCUSSION

An extensive experimental test-bed for AI based industrial applications is established with the support of IoT devices. Adopted industrial data sets show the impact power and battery lifetime of the IoT-driven portable devices product monitoring and process with high reliability. There are several experimental parameters as shown in Table II.

TABLE II. EXPERIMENTAL PARAMETERS

Parameter	Value
RSSIth	-85 dBm
Standard deviation (σ)	5dBm
Harvesting rate (β)	1000 Hz
Dutycycle	1%
Carrier frequency	5 GHz
Bandwidth	5 MHz
TP levels	{-5,-4, -3, 2, 1,0,1,2,3,4,5}
Maximum Transmission Power	0 dBm
Minimum Transmit power	-20 dBm
Operation time (T)	5 mints
Delay	300 sec
Data packet length	200 bytes
Data packet interval	100 sec
Data Rate	250 Kbps
Noise figure	7 dB
Noise PSD	-174 dBm/Hz
Wireless Channel	IEEE 802.15.4 (PHY and MAC)
Processing delay	2 mints

TABLE III. RELATIONSHIP BETWEEN PERFORMNCE METRICS

	Standard Deviation(dBm)			**Energy Consumption(mJ)**		
X/Y Axis	**FCDAA**	**PTPC**	**Baseline**	**FCDAA**	**PTPC**	**Baseline**
Sensor Nodes	low	moderate	high	low	high	high
Modulation Level	low	high	high	low	moderate	high
Duty-cycle	low	high	high	low	high	high
Time	low	high	high	low	high	high

Several key issues are examined during industrial process and monitoring by gathering large data sets [25] and developing novel mechanisms to manage the power and extend the battery lifetime of portable industrial devices. Moreover, overall test-bed consists of transmitter sensor node and BS with static and

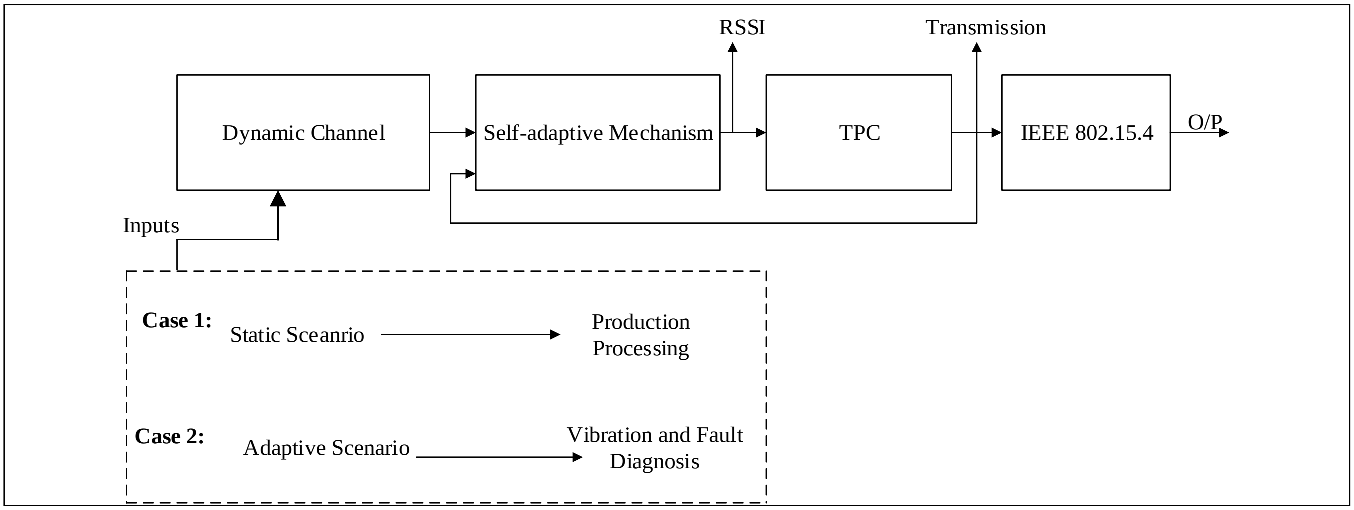
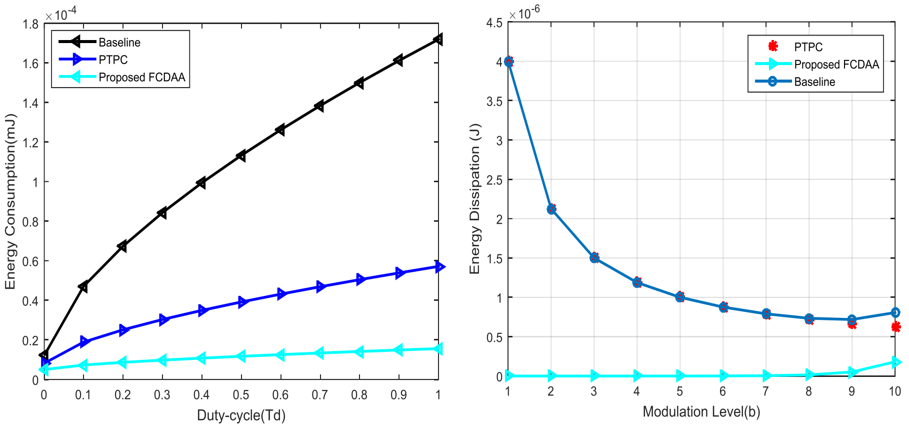
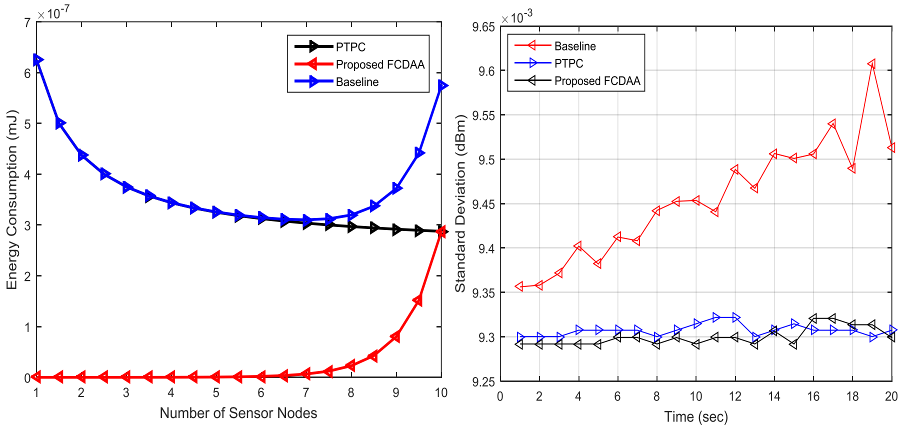


Fig. 4. Framework of Reliable data transmission in AI based edge computing platform over hybird TPC and duty-cycle network



(a) (b)

Fig. 5. a) Duty-cycle vs.Energy depletion, b) Tradeoff between Modulation level and Energy drain



(a) (b)

Fig. 6.a) Number of sensor nodes vs.Energy Consumption, b) Relationship between time and standard deviation

dydamic mechanisms, operation time T of 5 minutes, and delay t_0 of 200 ms. Fig.7 reveals the relationship between time (in sec) and the RSSI (in dBm) value or reliability of proposed FCDAA and conventional methods i.e., Baseline and PTPC over hybrid TPC and duty-cycle network. It is examined that there is less variation in the RSSI level of the proposed FCDAA unlike the traditional methods at the pre-defined RSSI target value. Stable RSSI level shows high reliability and reasonable energy drain. It must be noted that RSSI deviation is linearly proportional to the channel characteristics i.e., case 1:static (product processing) and case 2: dynamic (vibration and fault diagnosis) cases. Faster the vibration and fault diagnosis process, higher the channel deviation and less stable the RSSI values, hence less reliability and vice versa. Hence, it can be said that proposed FCDAA shows high reliability unlike orthodox methods i.e., Baseline and PTPC..In addition, the connection between data packet size w and energy depletion rate is established for different sensor platforms with clear representation. Besides, high deviation and unstable nature of the channel dissipates more energy in Baseline and PTPC than the proposed FCDAA. We observed that with the increase of the duty-cycle more energy is depleted for the conventional methods unlike the proposed FCDAA. In addition, the high sleep time of the sensor nodes strengthen the energy saving but the large wakeup time leads to more energy consumption for the traditional methods than the proposed FCDAA in industrial environment. Moreover, duty-cycle or wireless channel utilization, is merely concerned with the data traffic generation i.e., discrete or continuous mechanism in the industrial applications. With the increase of the duty-cycle PLR will increase at large extent in the conventional methods unlike in the proposed FCDAA. We analyzed that distance and energy drain are linearly

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proportional i.e., more energy is consumed by Baseline and PTPC and less with proposed FCDAA. But there is less energy drain in the proposed FCDAA, more in Baseline, and slightly more in the PTPC. Let's assume the threshold distance d_{th} is 1kilometer, where energy consumption can be reduced by using some resource scheduling algorithms with the condition $d \le d_{th}$, whereby distance between IoT devices in industrial application is denoted by d (which is 100m).

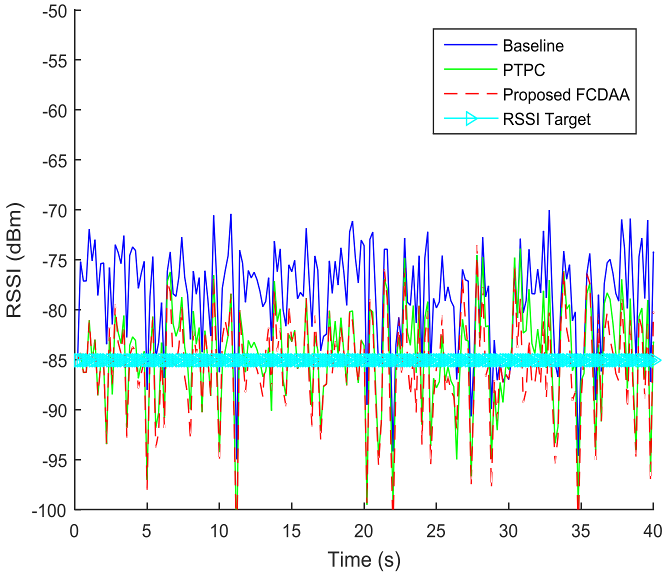

Fig. 7. Reliability optimization in hybird TPC and duty-cycle network

VI. CONCLUSION AND FUTURE RESEARCH

Power and battery-aware communication through portable IoT devices is very vital for industrial application due to rapid progress in the technological trends and practices. Also, industrial sector has revolutionized the entire landscape to boost the societal and economical needs. The challenging issue with today's industrial evolution is the resource-constrained nature of IoT-based portable devices. To remedy these challenegs this research contributes in three distinct ways. First proposes FCDAA by tuning duty-cycle and transmission power levels of the IoT based portable devices during sensing, processing and transmission tasks by considering large number of real-time datasets. Second, system-level battery model of IoT based portable devices is proposed. Third, data reliability model is proposed for IoT devices in AI driven edge computing platform for industrial platform. Through theoretical analysis with extensive real-time data sets and Monte Carlo simulation in MATLAB we concluded that significant amount of transmission power is dissipated at relatively less PLR and stable RSSI by Baseline (with very low energy saving), acceptable by proposed FCDAA (with high energy saving) and medium by PTPC (low energy saving). It has also been examined and interpreted that FCDAA fulfills the main requirement of RSSI and PLR by adopting AI driven edge computing platform for industrial applications. Hereafter, it can be claimed that proposed FCDAA is the potential candidates for energy saving in AI driven edge computing mechanism for industrial applications. Following are the limitations of the proposed FCDAA

- Relatively more complexity in integrating TPC and duty-cycle for AI driven IoT devices.
- hybird duty-cycle and TPC mechanism saves more energy with larger delays at base station or receiver side in AI-driven IoT devices.

In near future machine learning based self-adaptive joint wireless power transfer, modulation and coding techniques for big data management in industries will be focused. Besides, AI-driven Use-case for the smart industrial city will be proposed.

DISCLOSURES

There is no conflict of interest between all authors.

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