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Delay Analysis Wireless Sensor Networks Considering Energy Costs of Sensing and Transmission in Energy Harvesting Nature

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***Abstract* - Wireless sensor nodes lifetime can be enhanced by a means of Energy harvesting (EH). However, the randomness characteristic in the EH process for performing sensing operations and transmitting sensed information to the sink may cause significant delay. We consider the energy costs of both sensing and transmission unlike most existing studies on the delay performance of EH sensor networks, where only the energy consumption of transmission is considered. Specifically, we consider EH sensor that monitors some status property and adopts a harvest-then- use protocol to perform sensing and transmission. To study the delay performance, we consider two complementary metrics and derive their statistics analytically: 1) update age— how timely the updated information at the sink by measuring the time taken from when information is obtained by the sensor to when the sensed information is successfully transmitted to the sink and 2) update cycle—how frequently the information at the sink is updated by measuring the time duration between two consecutive successful transmissions. Our results show that the consideration of sensing energy cost leads to an important trade-off between the two metrics: more frequent updates result in less timely information available at the sink.**

Keywords: Energy harvesting, wireless powered communications, delay analysis, energy costs of sensing and transmission.

I. INTRODUCTION

This Wireless Sensor Networks (WSNs) can be defined as wireless networks which is self-configured and infrastructure less device used to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to sink where the data can be observed and analyzed. A base station or sink acts like an interface between users and the network. One can acquire required information from the network by posing queries and collecting results from the sink. Normally a wireless sensor network contains large number of sensor nodes which are hundred or thousand in number. The radio signals are helpful for sensor nodes to communicate among themselves. A wireless sensor node contains sensing and computing devices, radio transceivers and power components. Each node in a wireless sensor network (WSN) are internally resource constrained: they have limited storage capacity, processing speed, and communication bandwidth. After the sensor nodes are employed, they are responsible multi-hop communication by self-organizing an appropriate network infrastructure with them. Then the sensors in the network starts collecting the information of interest. Wireless sensor devices perform specific instructions or provide sensing samples which are responded to queries sent from a "control site". The working mode of the sensor nodes in the network may be either event driven or continuous. Global Positioning System (GPS) and local positioning algorithms can be used to obtain positioning information and location. Wireless sensor devices to act upon certain condition they can be equipped with actuators. Energy harvesting (EH) in the ambient environment from energy sources is a better solution to power wireless sensor networks (WSNs). In the literature [1]-[5] it has been demonstrated about the feasibility of powering WSNs by EH from solar, wind, vibration and radio-frequency (RF) signals. If an EH source is continuously or periodically or available, a sensor node can in theory be perpetually powered. There are several interesting and challenging issues in the design of EH WSN network.

A. Overview to Energy Harvesting

The proposed system uses an energy harvesting method to convert the natural energy into electrical energy. Energy harvesting also known as energy scavenging or ambient power or power harvesting by which energy is derived from external sources (e.g., thermal energy, wind energy,

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salinity gradients and kinetic energy, also known as ambient energy), collected and stored for small wireless autonomous devices, like those used in wireless sensor networks and wearable electronics in [2] [3]. A very small amount of power for low-energy electronics can be provided by the energy harvesters. The energy source for energy harvesters is present as ambient background for some large-scale generation costs resources as an input fuel such as oil, coal, etc. For example, In the operation of a combustion engine and in urban areas temperature gradient exits; there is a large amount of electromagnetic energy in the environment because of television broadcasting and radio. The battery in system stores the electrical signal and send it through the transmission lines to the users. A typical energy harvesting system has three components, the Energy source, the Harvesting architecture and the Load. Energy source refers to harvest the energy from the ambient source. Harvesting architecture refers to harness and convert the input ambient energy to electrical energy. Load refers to the activity that acts as a sink for the harvested energy and consumes energy. This system uses wireless sensor nodes to communicate the different node. A major role in Wireless Sensor Networks (WSNs) in the research field of multi-hop wireless networks as enablers of applications ranging from structural and environmental monitoring to human health control and border security. Research within this field has covered a wide spectrum of topics, leading to advances in localization, node hardware, protocol stack design, and tracking techniques and energy management and also enables manufacture to use low power device.

II. LITERATURE REVIEW

Recently, there has been an increase of research interests in radio frequency (RF) energy harvesting/scavenging technique which is the capability of transforming the received RF signals into electricity. This technique becomes an important solution to power energy-constrained wireless networks. Conventionally, the energy-constrained wireless networks, such as wireless sensor networks, which largely confines the network performance have a limited life time [4] [5]. In contrast, an RF energy harvesting network (RF-EHN) in a radio environment has a sustainable power supply. Therefore, the wireless devices of RF energy harvesting capability allow to harvest energy from RF signals for their information processing and transmission. RF-EHNs have found their applications quickly in wireless sensor networks, wireless charging networks, and wireless body systems. The Wireless Power Consortium is also making the efforts of establishing an international standard for the RF energy harvesting technique with the increasingly emerging applications of RF energy harvesting. The radio signals with frequency range from 300GHz to as low as 3kHz are used as a medium to carry energy in a form of electromagnetic radiation in RF energy harvesting. RF energy transfer and harvesting are one of the wireless energy transfer techniques. The other techniques are magnetic resonance coupling and inductive coupling. Inductive coupling is based on magnetic coupling tuned to resonate at the same frequency that delivers electrical energy between two coils. Magnetic resonance coupling to generate and transfer electrical energy between two resonators by utilizing evanescent-wave coupling. The resonator is formed in an induction coil by adding a capacitance in it [6] [7]. Both above two techniques are near-field wireless transmission featured with conversion efficiency and high-power density. The coupling coefficient that depends on the power transmission efficiency, which depends on the distance between two coils/resonators. Besides, both the resonance coupling and inductive coupling require calibration and alignment of coils at receivers and transmitters. Therefore, they are not suitable for remote and mobile charging. In contrast, there are no such limitations on RF energy transfer. The RF energy transfer can be defined as a far-field energy transfer technique. Thus, RF energy transfer is suitable for powering a larger number of devices distributed in a wide area. According to the reciprocal of the distance between transmitter and receiver the signal strength of far-field RF transmission is attenuated, specifically, 20 dB per decade of the distance. The RF energy transfer technique has advantages over effective energy transfer distance.

III. ANALYSIS OF DELAY CONSEDERING ENERGY COST OF SENSING AND TRANSMISSION

A. Design challanges

Modelling of energy costs is an important design consideration for EH WSNs. There are three main types of energy costs in wireless sensors (1) energy cost of RF transmission and reception includes idle listening, (2) energy cost of information sensing and processing, and

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(3) energy cost of other basic processing while being active. Generally, the energy cost of transmission is much higher compared to other basic processing. Hence, by ignoring the energy cost of sensing most of the current work on EH WSNs has considered only the energy cost of transmission. But for some sensors such as high-resolution acoustic and high-rated seismic sensors, the energy cost of transmission is being lower than the energy cost of sensing. Hence, it is important to model the energy cost of sensing accurately in WSNs. The energy arrival process is inherently time-varying in nature for WSNs powered by EH from the ambient environment. These fluctuations in the energy arrival process are characterised by its coherence time and can be slow or fast. For instance, the coherence time is on the order of minutes or hours for the case of EH from a solar panel on a clear day with abundant sunshine [3]. The coherence time can be on the order of milliseconds in the case of wireless energy transfer via RF signals, which is comparable to the duration of a communication time slot. In the latter case the energy arrival process can be modelled as a random process where the amount of harvested energy follows some probability distribution. For example, papers studying EH from RF signals often assume the gamma distribution and exponential distribution. However, many energy arrival processes in practice cannot be accurately modelled by using exponential or gamma distributions. It is still largely an open problem to consider the more general probability distribution for modelling the amount of energy arrival.

The delay performance is a key design challenge in many sensor network applications. The effects of randomness in both arrivals of the harvested energy and multiple data packets on the overall transmission time were considered. A single data packet and wireless channel randomness in the energy arrival process, were considered in the analysis of transmission delay. A comprehensive analysis of EH WSNs considering a realistic model the delay performance of sensor energy costs, has not been investigated in the literature.

B. Paper Contributions

We consider a status monitoring with one sensor-sink pair. From an ambient energy source, the sensor is solely powered by EH. The sensor monitors periodically and senses the current environment, i.e., it generates status information about variables of interest, and then transmits to the sink about the status-information-containing packet. Due to fading in the transmission channel after several failed retransmissions the packets are successfully transmitted to the sink, and the status is updated at the sink. To assess the delay performance, we adopt two different metrics:(i) The time duration between the time of generation of the status information at the sink and the time at which it is updated at the sink, is known as update age (or freshness) and (ii) The time duration between one status update at the sink to the next is known as update cycle (or frequency). They are complementary measures to each other [8] [9]. The updated status information at the sink is much timelier then it indicates smaller update age but does not indicate when the next update status information will be received. The more frequent status updates at the sink indicates smaller update cycle but does not indicate when the current updated status information was originally generated. Thus, the quality of a status monitoring system, i.e., the status update frequency and freshness, is comprehensively captured by the update cycle and update age, respectively. We account for the fact that both consume energy while sensing and transmission operations. From the harvest-then-use and save-then-transmit communication protocols for EH nodes in wireless networks which are simple to implement in practice, we use a harvest-then-use protocol for the EH sensor. In our proposed protocol, after harvesting sufficient energy the sensor performs sensing and transmission. We impose a time window for retransmissions, to limit the delay due to retransmissions [15]. The delay performance of the considered harvest-then-use protocol is analysed. The main contributions of this paper are as follows:

• The delay performance of EH sensor networks can be considered by updated age which is delay due to the information transmission from the sensor to the sink, and update cycle which characterizes the frequency of updating the information held by the sink.

• A wide range of EH process can be possible by considering general distribution such as deterministic energy arrival model and a random energy arrival model. We analytically derive the statistics of both the update cycle and the update age by considering Rayleigh fading wireless channel.

• when studying the delay performance whether to increase or reduce the number of allowed retransmission attempts for each sensed information we take the energy costs of both sensing and transmission into account, because both sensing and transmission consume energy. This in turn results in a trade-off between the update age and the update cycle. The importance of modelling the energy cost of sensing is emphasized by trade-off.

IV. SYSTEM MODEL

In transmission scenario the sensor transmits its sensed information to a sink periodically, as shown in Fig. 1. Sensing and transmission are the two main functions of sensor, each having individual energy cost. The half-duplex operation, i.e., sensing and transmission occur at the different time is employed [3] [10]. The sensor first needs to spend a certain amount of time on EH, to perform either sensing or transmission. The battery stores the harvested energy. Let us consider that the battery cannot charge and discharge at the same time. In addition, the battery has sufficient charge capacity such that it never reaches its maximum, since battery capacity typically ranges from joules to thousands of joules.

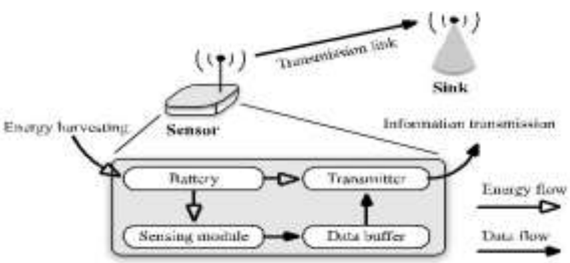

Fig. 1. Illustration of system model and sensor components

We adopt a time-slotted or block-wise operation, following state-of-the-art EH sensor design practice. We assume that one-time block of duration T seconds is performed for one sensing operation or one transmission. We assume that the sensor checks the battery energy state at the beginning of each block and decides to perform either sensing, transmission, or energy harvesting. Thus, we define the following types of time blocks of energy cost/harvesting:

• Sensing Block (SB): The sensor processes and packs sensed information into a data packet by sampling the status information. ESB denotes the energy cost in a SB.

• Transmission Block (TB): The sensor transmits the newest generated data packet to the sink from the last sensing operation with energy cost ETB, i.e., the transmit power is PTB = ETB/T. Then the sink sends successful packet reception by sending a one-bit feedback signal to the sensor. we have a successful transmission block (STB), If the transmission is successful; otherwise, we have a failed transmission block (FTB). We consider that successes/failures of each TB are mutually independent. The probability of a TB being a FTB, i.e., transmission outage, is denoted by Pout.

• Energy-harvesting block (EHB): The sensor harvests energy and stores the energy in its battery from the ambient environment.

A. Proposed Sensing and Transmission Protocol

The system contains many wireless sensors which collect data from about a particular parameter of the environment and send it to sink [6] [11]. Now sensor harvest energy from the environment to carry out its operation. For this operation system follows following protocol:

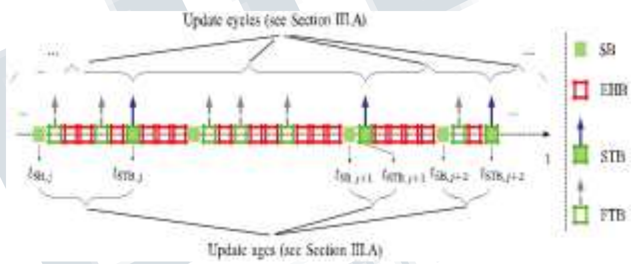

Fig. 2. Illustration of update cycle and update age.

The system contains many wireless sensors which collect data from about a particular parameter of the environment and send it to sink [6] [11]. Now sensor harvest energy from the environment to carry out its operation. For this operation system follows following protocol:

1. First, to harvest enough energy i.e., ESB + ETB the sensor uses several EHBs, and then a SB and a TB occur.
2. If the transmission in the TB is successful, i.e., we have a successful transmission block STB, the sensor harvests energy until the battery energy exceeds ESB + ETB for the next sensing period.
3. If the transmission in the TB fails, i.e., we have a failed transmission block FTB, the sensor goes back to harvesting energy until battery energy exceeds ETB and performs retransmission.
4. Until the sensed information is successfully transmitted to the sink or the time window for retransmissions W − 1 is reached retransmission may occur several times. The sensor goes back to harvesting the energy for a new sensing operation when the data packet at the sensor is dropped.
5. Outage probability at a given SNR calculated in this way. Once the outage probability is calculated, then PMF

of the update age and update cycle is calculated.

In the example shown, the first block in Fig. 2 (having window size W=7) is a SB, followed by two FTBs (and two EHBs in between). Since the third TB is a STB, the sensed information is successfully transmitted to the sink. Then, three EHBs are used by the sensor to harvest energy to conduct sensing in the next SB [12] . After the second SB, there are three TBs during 7-time blocks, and all of them are FTBs.

Thus, after reaching W=7 the retransmission process is terminated. As a result, the sensed information in the second SB is not transmitted to the sink.

B. Proposed Models for Energy Arrival

We consider that the harvested energy in each EHB could either change or remain constant from block to block. The former is referred to as random energy arrival, while the latter is referred to as deterministic energy arrival. When the coherence time of the EH process is much larger than the duration of the entire communication session Deterministic energy arrival is an appropriate model, such as EH by solar panel on clear days [13]. In this paper, we denote this as deterministic energy arrival process. For simplicity, we also assume that ESB and ETB represent integer multiples of the harvested energy by one EHB, ρ. We consider independent and identically distributed (i.i.d) random energy arrival model for random energy arrivals. This energy arrival model is considered as general random energy arrival process. The previously considered gamma and exponential distributions become different cases of the general probability distribution. We will provide results for this important special case and referred to it as exponential energy arrival process.

C. Delay-Related metrices

By considering sensing and transmission protocol we use two metrics to measure the delay performance. In Fig. 2, we use tSTB, j to denote the block index for the j th STB during the transmission and sensing operation. Note that the information is updated at the sink for a successful transmission [14]. Also, the information content is important to associate with its transmission. We use tSB, j to denote the block index for the SB in which the sensed information is transmitted in the j th STB i.e., status information sensed at tSTB, j is successfully transmitted to the sink at tSTB, j. Next, two delay-related metrics, expressed in terms of the number of time blocks are defined:

V. UPDATE AGE AND UPDATE CYCLE

Update age: The update age is given by the number of time blocks from t_{SB}, j to t_{STB}, j, for the j th STB. The j th update age is given by

$$T_{UA,j=t_{STB,j}-t_{SB,j}} \qquad j=1,2,3 \ldots\ldots\ldots \quad (1)$$

The update age measures elapsed time from the generation of a status-information-containing packet to the reception of the packet, i.e., status update, from sensor to the sink. The outdated status is received by the sink implies larger update age. The freshness of the updated status information is captured by the update age.

Update cycle: The update cycle is given by the number of time blocks from $t_{STB}, j-1$ to t_{STB}, j, for the j th STB. The j th update cycle is

$$T_{UC,j=t_{STB,j+1}-t_{STB,j}} \qquad j=1,2,3 \ldots\ldots\ldots \quad (2)$$

The update cycle measures elapsed time from one status update at the sink to the next. The update cycle does not reflect the update freshness at the sink. The update cycle considers the delay due to dropped data packets. The update age and update cycle jointly capture the update frequency and freshness, to provide the delay performance of a status monitoring system matrices.

Modelling Delay-Related Metrics as i.i.d. Random Variables:

The energy level after each TB is zero for deterministic energy arrival process. For a general random energy arrival with pdf containing at least one positive right-continuous point, f (ϵ), the energy level the steady-state distribution after each TB has pdf

$$g\,(\epsilon) = \frac{1}{\rho}\left(1 - F\,(\epsilon)\right), \qquad (3)$$

where f (ϵ) is the cumulative distribution function (cdf) corresponding to f (ϵ) and ρ is the average harvested energy.

A. Update Age:

Deterministic Energy Arrival Process: The update age pmf of deterministic energy arrival process is given by

$$\Pr\{T_{UA} = k\} = \frac{(1 - P_{out})(P_{out})^{n-1}}{(P_{suc})},$$

$$K = 1 + (n - 1)\left(\frac{\varepsilon_{TB}}{\rho} + 1\right) \qquad (4)$$

Where $n = 1,2,..\hat{n}, \hat{n} = 1 + \left\lfloor \frac{W-1}{1+\frac{\varepsilon_{TB}}{\rho}} \right\rfloor, P_{suc} = 1-(P_{out})^{\hat{n}}$

The average update age of deterministic energy arrival is given by

$$\bar{T}_{UA} = \sum_{n=1}^{\hat{n}}(1+(n-1)(\frac{\varepsilon_{TB}}{\rho}+1))\frac{(1-P_{out})(P_{out})^{n-1}}{(P_{suc})} \quad (5)$$

General Random Energy Arrival Process: The update age pmf of general energy arrival process is given by

$$\Pr\{T_{UA}=k\} = \begin{cases} \frac{1-P_{out}}{P_{suc}}, k=1 \\ \frac{(1-P_{out})}{P_{suc}}\sum_{n=2}^{k}(P_{out})^{n-1}\left(G_{k-n-1}\left((n-1)\varepsilon_{TB}\right)\right. \\ \left.-G_{k-n}\left((n-1)\varepsilon_{TB}\right)\right), 2 \le k \le W \end{cases} \quad (6)$$

The average update age for general random energy arrival process is given by

$$\bar{T}_{UA} = \frac{1-P_{out}}{P_{suc}}(1+\sum_{l=2}^{W} l \sum_{n=2}^{l}(P_{out})^{n-1}(G_{l-n-1}\left((n-1)\varepsilon_{TB}\right) -G_{l-n}\left((n-1)\varepsilon_{TB}\right) \quad (7)$$

Exponential Energy Arrival process: The update age pmf of exponential energy process is given by

$$\Pr\{T_{UA}=k\} = \begin{cases} \frac{1-P_{out}}{P_{suc}}, k=1 \\ \frac{(1-P_{out})}{P_{suc}}\sum_{n=2}^{k}(P_{out})^{n-1} \\ \times pois(k-n), 2 \le k \le W \end{cases} \quad (8)$$

where

$$\bar{T}_{UA} = \frac{(1-P_{out})}{P_{suc}}\begin{pmatrix} 1+\sum_{l=2}^{W} l \sum_{n=2}^{l}(P_{out})^{n-1} \\ pois\left(l-n,(n-1)\frac{\varepsilon_{TB}}{\rho}\right) \end{pmatrix} \quad (9)$$

As W gets larger asymptotic bound of is independent of energy arrival distribution

$$\lim_{W\to\infty} \bar{T}_{UA} = 1 + \frac{P_{out}}{1-P_{out}}\left(\frac{\varepsilon_{TB}}{\rho}+1\right) \quad (10)$$

i) From the above equations energy cost of sensing , ESB, because the delay is only affected by the retransmissions and energy harvesting that happen after the sensing operation. This might give the fact that delay is not affected by energy cost of sensing. However, update age is only one of the two delay metrics, and the energy cost of sensing has important impacts on update cycle.

ii) The average update age is increased by allowing a larger window for retransmissions. This gives that retransmissions should be avoided, i.e., W = 1. However, we do not consider update age where sensed information is not successfully transmitted to the sink. In this situation the update cycle implicitly captures such cases.

Update Cycle: In harvest-then-use protocol consider the dynamics of an energy arrival process and the probability of successful/failed transmission, the update cycle for deterministic, exponential energy arrival and general random processes are analysed.

Deterministic Energy Arrival Process: The update cycle pmf for a deterministic energy arrival process is given by

$$\Pr\{T_{UC}=k\} = (1-P_{out})(P_{out})^{n-1+m\hat{n}}$$
$$k = \left(\frac{\varepsilon_{TB}+n\varepsilon_{TB}}{\rho}\right)+n+1+m(\frac{\varepsilon_{SB}+\hat{n}\varepsilon_{TB}}{\rho}+(\hat{n}+1) \quad (11)$$

Where n=1,2,… , m=0,1,2….

The average update cycle pmf for a deterministic energy arrival process is given by

$$\hat{T}_{UC} = \frac{(P_{out})^{\hat{n}}}{1-(P_{out})^{\hat{n}}}\left(1+\hat{n}+\frac{\varepsilon_{SB}+\hat{n}\varepsilon_{TB}}{\rho}\right)+\frac{\varepsilon_{SB}}{\rho}+1$$
$$+(1+\frac{\varepsilon_{SB}}{\rho})\frac{1-P_{out}}{1-(P_{out})^{\hat{n}}}\sum_{n=1}^{\hat{n}} n(\,(P_{out})^{n-1} \quad (12)$$

General Random Energy Arrival Process: The update cycle pmf for general random energy arrival process is given by

$$\Pr\{T_{UC}=k\} = \sum_{m=0}^{\hat{m}}\begin{pmatrix}\zeta(\varepsilon_{SB}+\varepsilon_{TB})*\zeta(\varepsilon_{SB})*\ldots* \\ \zeta(\varepsilon_{SB})*\vartheta*\vartheta*l\end{pmatrix}$$
$$(k-m(1+W)-1), k=2,3,.. \quad (13)$$

The average update cycle pmf for general random energy arrival process is given by

$$\hat{T}_{UC} = \frac{(1-P_{suc})}{P_{suc}}\left(\frac{\varepsilon_{SB}}{\rho}+\hat{V}+W+1\right)+\frac{\varepsilon_{SB}+\varepsilon_{TB}}{\rho}+\bar{T}_{UA}+1. \quad (14)$$

Exponential Energy Arrival Process: The update cycle pmf for exponential energy arrival process is given by

$$\Pr\{T_{UC}=k\} = \sum_{m=0}^{\hat{m}}\begin{pmatrix}\zeta(m+1)\varepsilon_{SB}*\varepsilon_{TB} \\ *\ldots\ldots\ldots*\vartheta*\vartheta*l\end{pmatrix}, k=2,3,. \quad (15)$$
$$(k-m(1+W)-1)$$

The average update cycle pmf for Exponential energy arrival process is given by

$$\hat{T}_{UC} = \frac{(1-P_{suc})}{P_{suc}}\left(\frac{\varepsilon_{SB}}{\rho}+\hat{V}+W+1\right)+\frac{\varepsilon_{SB}+\varepsilon_{TB}}{\rho}+\bar{T}_{UA}+1. \quad (16)$$

i)We know that affected by the energy cost of sensing, ESB. To harvest an enough energy to perform sensing

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operation(s) between adjacent STBs a larger ESB means more EHBs are required.

ii) The average update cycle is shortened for larger window for retransmissions, because successful transmissions can be possible by allowing more retransmissions. This might suggest that it is also better reduce the update cycle to increase W. But increasing W increases the update age. Therefore, there is a trade-off between the two metrics.

VI. NUMERICAL RESULTS

The typical outdoor range for a wireless sensor is from 75 m to 100 m. Hence, we set the distance between the sensor and the sink as d = 90m and the path loss exponent for the sensor-sink transmission link as λ = 3. The duration of a time block is T = 5ms. The noise power at the sink is σ2 = −100 dBm. The average harvested power is 10 mW, i.e., average harvested energy per time block, ρ = 50 µJ. Unless otherwise stated, we set the power consumption in each TB, PTB = 40 mW, i.e., ETB = 200 µJ. Note that this includes RF circuit consumption (main consumption) and the actual RF transmit power Ptx = −5 dBm6 and we set the power consumption in each SB as PSB = 50 mW [10], i.e., ESB = 250 µJ. In the following calculations, power and SNR related quantities use a linear scale. We assume that a transmission outage from the sensor to the sink occurs when the SNR at the sink γ , is lower than SNR threshold γ = 40 dB.Pmfs of update age and update cycle with different energy arrival processes:

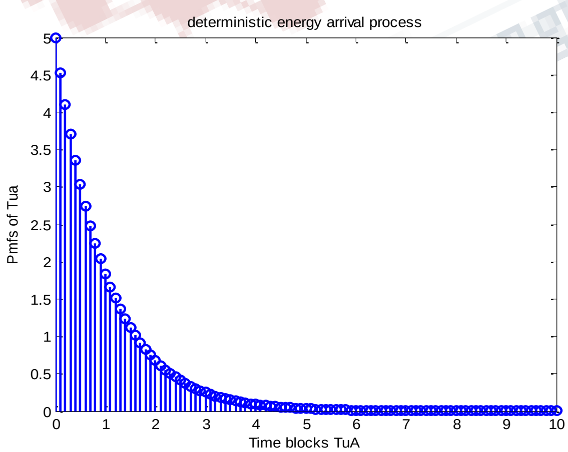
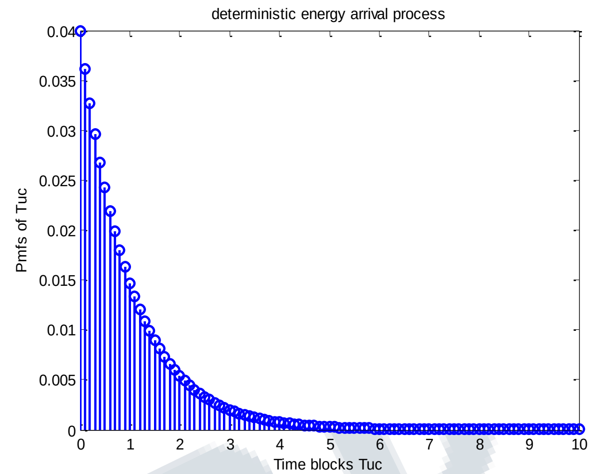
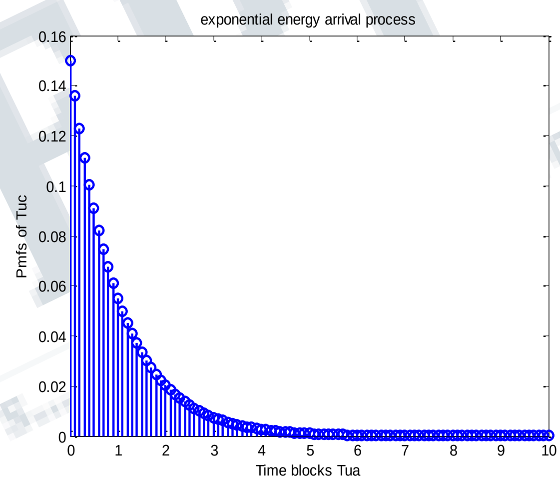


Fig. 3 pmfs for T_{UA} and T_{UC} with deterministic energy arrival processes.





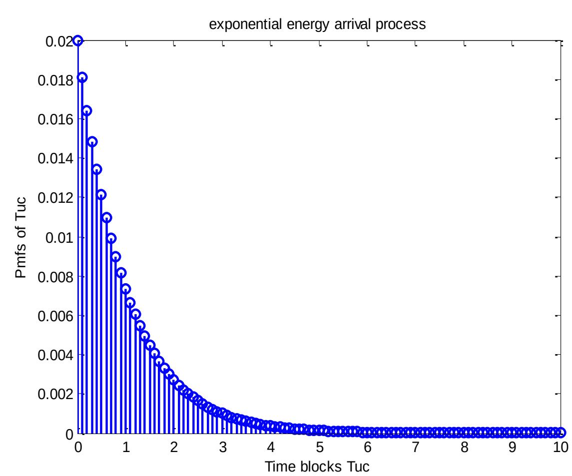


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Fig 4. Pmfs for T_{UA} and T_{UC} with exponential energy arrival process

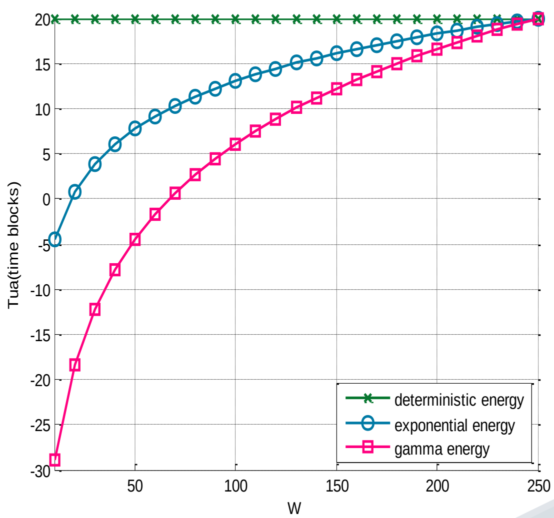

Fig. 5. Average Update age versus W with different energy arrival processes.

VII. CONCLUSION

PMFs of different types of energy arrivals process are different for update age and update cycle. Transmission rate decreases during the random energy arrival process. There is trade-off between update age and update cycle in terms of energy cost. Finding an optimal value of update age and update cycle will reduce the energy cost. Also use of deterministic energy process preferable over random energy arrival process model. Study of impact of non-deterministic time for receiving feedback signal at the sensor can be the future scope of the paper.

REFERENCES

[1] S. Sudevalayam and P. Kulkarni, “Energy harvesting sensor nodes: Survey and implications,” IEEE Commun. Surveys Tuts., vol. 13, no. 3,pp. 443–461, Sep. 2011.

[2] L. Xiao, P. Wang, D. Niyato, D. Kim, and Z. Han, “Wireless networks with RF energy harvesting: A contemporary survey,” IEEE Commun. Surveys Tuts., vol. 17, no. 2, pp. 757–789, May 2015.

[3] Wanchun Liu, Xiangyun Zhou, Salman Durrani and Hani Mehrpouyan, “Energy Harvesting Wireless Sensor Networks: Delay Analysis Considering Energy Costs of Sensing and Transmission” IEEE Commun., , vol. 15, no. 7, july 2016.

[4] K. Huang and X. Zhou, “Cutting last wires for mobile communication by microwave power transfer,” IEEE Commun. Mag., vol. 53, no. 6, pp. 86– 93, Jun. 2015.

[5] I. Krikidis, S. Timotheou, S. Nikolaou, G. Zheng, D. W. K. Ng, and R. Schober, “Simultaneous wireless information and power transfer in modern communication systems,” IEEE Commun. Mag., vol. 52, no. 11, pp. 104–110, Nov. 2014.

[6] S. Mao, M. H. Cheung, and V.Wong, “Joint energy allocation for sensing and transmission in rechargeable wireless sensor networks,” IEEE Trans. Veh. Technol., vol. 63, no. 6, pp. 2862–2875, Jul. 2014.

[7] H. Mahdavi-Doost and R. Yates, “Energy harvesting receivers: Finite battery capacity,” in Proc. IEEE Int. Symp. Inf. Theory (ISIT), Jul. 2013, pp. 1799–1803.

[8] T. Wu and H.-C. Yang, “On the performance of overlaid wireless sensor transmission with RF energy harvesting,” IEEE J. Sel. Areas Commun., vol. 33, no. 8, pp. 1693–1705, Aug. 2015.

[9] A. A. Nasir, X. Zhou, S. Durrani, and R. A. Kennedy, “Wireless-powered relays in cooperative communications: Time-switching relaying protocols and throughput analysis,” IEEE Trans. Commun., vol. 63, no. 5, pp. 1607– 1622, May 2015.

[10] Z. Ding, S. Perlaza, I. Esnaola, and H. V. Poor, “Power allocation strategies in energy harvesting wireless cooperative networks,” IEEE Trans. Wireless Commun., vol. 13, no. 2, pp. 846–860, Feb. 2014.

[11] S. Luo, R. Zhang, and T. J. Lim, “Optimal save-then-transmit protocol for energy harvesting wireless transmitters,” IEEE Trans. Wireless Commun., vol. 12, no. 3, pp. 1196–1207, Mar. 2013.

ISSN (Online) 2394-2320

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Vol 5, Issue 2, February 2018

[12] J. Yang and S. Ulukus, “Transmission completion time minimization in an energy harvesting system,” in Proc. IEEE 44th Annu. Conf. Inf. Sci. Syst. (CISS), Mar. 2010, pp. 1–6.

[13] S. Kaul, R. Yates, and M. Gruteser, “Real-time status: How often should one update?” in Proc. IEEE INFOCOM, Mar. 2012, pp. 2731–2735.

[14] M. Costa, M. Codreanu, and A. Ephremides, “Age of information with packet management,” in Proc. Int. Symp. Inf. Theory (ISIT), Jun. 2014, pp. 1583–1587.

[15] P. Lee, Z. A. Eu, M. Han, and H. Tan, “Empirical modeling of a solar-powered energy harvesting wireless sensor node for time-slotted operation,” in Proc. IEEE Wireless Commun. Netw. Conf. (WCNC), Mar. 2011, pp. 179–184.