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# Energy Constraint Access Control For IoT Node

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## ABSTRACT

*The need for energy efficiency in IoT and Wireless Sensors Networks (WSNs) has been gaining increasing attention in the last years, and a large variety of energy-aware protocols at all layers of the protocol stack have been proposed. To extend the network lifetime, two major directions exist: when the battery represents the only source available to the device, the effort is put in the minimization of the energy consumption instead, when devices have Energy Harvesting. The primary goal of this paper is to implement an optimal MAC layer protocol that increases the network lifetime of IoT nodes that is a Time Division Multiple Access (TDMA)-based access scheme with optimization, which efficiently allocates resources to heterogeneous IoT nodes. We used realistic rate-distortion curves to quantify the impact of compression on the data quality and propose a complete energy model that includes the energy spent for processing and transmitting the data. For different energy constraints the network life time is improved.*

***Keyword:—*** *IoT, MAC, Time Division Multiple Access (TDMA), Optimization*

## 1. INTRODUCTION

The energy efficient communication strategy for Internet of Things (IoT) with the objective to minimizing of the energy consumption and quality of service is introduced. In forthcoming wireless sensor networks play major role in the data intelligent and gathering. These are made possible by the availability of sensors that are slighter, inexpensive and perceptive. Sensors communicate with each another in a network with the assistance of wireless interfaces [1]. Due to tiny devices has limited battery energy for communicating wirelessly. Limitation can be contingent heavily on the application and associated factors such as the, cost, hardware, environment and system constraints. In this thesis explores the energy efficient communication by using the green computing approaches [2].

The term of "energy efficiency" is used in IOT as a major consideration and one of the most important requirements. IOT nodes are expected to operate for long periods of time, running of batteries or ambient energy sources. Because the biggest consumer of energy is the radio, many researchers have focused on creating energy efficient or low energy consuming MAC protocols [3-5]. The most important challenge in relation to all IoT nodes is to minimize energy consumption. Increasing the energy efficiency of the network leads to prolong the battery and network lifetime. This may be achieved by considering energy awareness issues in all aspects of design and operation of each sensor node. Moreover, energy saving protocols and techniques need to be addressed for collective groups of communicating sensor nodes in order to have better overall performance and improved energy efficiency within the IoT network [6].

Since wireless networks operate in a broadcast medium, these networks require a Medium Access Control (MAC) layer to resolve contention in a random multi-access environment. The MAC layer protocols must be sensitive to the specific needs of a wide variety of sensing applications. In an effort to make inexpensive sensors ubiquitous, these sensors tend to have limited processing capability, memory capacity, and battery life. We focus on the implement of the Medium Access Control (MAC) layer protocols, this have a strong impact on better energy efficiency, since the usage of the RF channel may be very energy efficient and demanding [8]. And also random access is sometimes considered over coordinated access schemes [9, 10]; TDMA-based schemes have provided a valid choice in IoT systems [11, 12]. Contention-based protocols are flexible and require low synchronization costs, but generally lead to a high energy wastage due to collisions and idle listening, which can instead be avoided in reservation-based protocols, at the cost of some additional synchronization overhead [13-18]. In applications like environmental monitoring, the set of nodes involved in the data reporting operation is usually fixed, and dynamic sensors typically report data periodically with predefined time, which makes TDMA method, is best suited for IoT [19]. Indeed, by properly use of the slot allocations to the traffic data pattern, idle periodic listening and collisions can be completely removed, thereby improving the lifetime of the network. To this aim, appropriate duty cycling methods are typically adopted [20-23]. Often, TDMA is combined with Carrier Sense Multiple Access (CSMA) method, since these hybrid ways of use, which offer flexibility when choosing the frame size and assigning time slots to each IoT nodes [24].

## II. RELATED WORK

Internet of Things provides wireless infrastructure with distinctive identifiers and the capability to discussion information over a network. The world of electrical, communicating devices is growing at a rapid pace as a result of the growth of consumer electronics in the 1980’s and 1990s, the Internet in the 1990s and the 2000s, and the increasingly mobile connected devices of the 2000s and 2010s. The growth is expected to continue over the next decades with the breakthrough of the Machine-to-Machine (M2M) and IoT correspondence; it is assessed by Cisco to achieve more than 50 billion associated gadgets by 2020 Evans (2011), and others expect numbers that differ somewhat depending on the interpretation of “devices” and focus on different markets Perera et al (2015) [4].

### *Access Control in IoT*

Access control is a mechanism for monitoring service requests issued to a service provider and managing when a communication must or must not be approved. Access control can also enable the identification of a consumer of a service and the provision of relevant information about that consumer to the service, enabling the possibility of providing customized services.

As in the previous section, the use of standard mechanisms in recommended to maintain interoperability. However, an exception arises in this case because the standard solutions have shortcomings that require the implementation of a new, more efficient access control mechanism for IoT applications. This section describes the most common access control standards and their shortcomings and proposes such an efficient access control mechanism [3-6].

The example that most corroborates the validity of using TDMA in IoT networks is the Time-Slotted Channel Hopping (TSCH) mode of the IEEE 802.15.4e standard [8]. It was introduced in 2012 by the Internet Engineering Task Force, and it currently represents the main emerging standard for Low power and Lossy Networks (LLNs) for industrial automation and process control. The design of our MAC scheme uses data fidelity as a key performance metric, defined as the distortion of the transmitted data with respect to their uncompressed version. Other studies in the literature consider joint source coding and transmission policies and investigate the tradeoff between energy efficiency and data quality [9]. In [10], an online joint compression and transmission optimization strategy is investigated for sensors with EH capabilities that generate correlated information, but how to schedule transmissions in a time slot is not treated.

In [11], the authors derive optimal compression policies for a single sensor in order to minimize the long-term average distortion subject to the energy sustainability of the sensor, where power control is used to adapt the transmission to the status of the fading channel. In [12], energy allocation strategies are proposed with the goal of minimizing the signal distortion when several sensors measure the same process of interest and exploit data fusion techniques, but analytical results are derived only for a two-node system. Finally, [13] proposes a TDMA scheduling where time slots are allocated in a dynamic fashion based on the spatial correlation of the transmitted signals.

In this work, we aim at determining the optimal operating point in the tradeoff between network lifetime and signal quality in order to derive a TDMA-based scheduling strategy for resource-constrained nodes. With respect to our previous work [1], we introduce two major novelties. First, we allow for the dismission of some users from transmission when it is impossible to have all devices meet their requirements in a frame. Second, we relax the full Channel State Information (CSI) assumption, since in realistic scenarios with fast fading it may be impractical to perfectly know the channel realizations a priori, and devices rather have only statistical CSI for future slots.

## II. SYSTEM MODEL

In the previous section, it is clear that, TDMA based MAC layer protocol is used with IOT nodes to limit the extra communication between nodes of the network hence increasing the lifetime and decreasing the energy consumption in IOT [9]. However, to optimize this strategy, these protocols need to be evaluated to enhance their capabilities. These algorithms are implemented and simulated, in order to decrease the energy and resource consumption in IoT.

### *Data Generation, Compression, Processing and Transmission*

Nodes generate data by collecting measurements from the surrounding environment or by serving as relays for farther nodes and compressing its data using a lossy compression scheme, which may be source specific. The compression operation affects the quality of the transmitted information and introduces a distortion [1, 19].

Data processing consists in executing the compression algorithm. A generic compression and processing energy consumption is, $E_{CP}$ of each node [1]. However, in real devices the power amplifiers may have inefficiencies; therefore the power injected into the channel is only a fraction of the device power consumption for transmission is $E_{TX}$. Although, ideally, the device energy consumption is only given by the radio module and the data processing, in practice there are also other effects to take into account, such as a) the energy spent to generate the sensor data, b) the synchronization costs, c) the energy spent to switch between sleep and active modes, and d) the energy losses due to the device circuitry is $E_C$. The total energy consumption of node i in frame k can obtain by summing,

$$E_{TOTAL} = E_{CP} + E_{TX} + E_C \tag{1}$$

### *Optimization Problem*

Our goal is to find a joint compression-transmission policy that decides how much to compress the data and how much time and power to assign to each node in each frame, Energy Allocation Problem (EAP). EAP assumes that the functions $f^{(k)}_{FOP}(E^{(k)})$ is known, and focuses on the optimization of the allocation vector $E^{(k)}$ over multiple frames. Formally, we have,

$$\begin{aligned} \text{EAP:} \quad & D^{\star}_{\text{mean}} \triangleq \min_{\mathbf{E}} \frac{1}{n} \sum_{k=1}^{n} f^{(k)}_{\text{FOP}}(\mathbf{E}^{(k)}), \\ \text{subject to:} \quad & \textstyle\sum_{j=1}^{n} E^{(j)}_i \le B^{(0)}_i, \quad \forall i, \\ & f^{(k)}_{\text{FOP}}(\mathbf{E}^{(k)}) \text{ is feasible}, \quad \forall k. \end{aligned} \tag{2}$$

The distortion performance corresponding to a certain energy allocation E and determine the optimal energy allocation.

### *Random Alternate Convergence Algorithm:*

Based on EAP that focuses on one user at a time, we propose an alternate approach to solve EAP, i.e., to optimize the energy allocation of each user in the different slots in order to minimize the mean distortion metric returned by the FOP solution [1-4]. In particular, we use Algorithm to solve the general problem. The key idea is to perform the optimization in all iteration until the distortion of every user in every frame, does not change further.

```
Algorithm  Random Alternate Convergence Algorithm
Initialize a feasible $\mathbf{E}$
$D_{\text{mean}} \leftarrow \infty$
while $D_i^{(k)}, \forall i, \forall k$ have not converged do
    for $\ell = 1, \dots, N$ do
        $\mathbf{E}_\ell \leftarrow$ solve $\text{EAP}_\ell(\mathbf{E})$
        $v \leftarrow$ prob. vector of size $\sum_k \chi\{E_\ell^{(k)} = \overline{E}_\ell^{(k)}\}$
        $S \leftarrow \sum_{k=1}^{n} E_\ell^{(k)}$                ▷ consumed energy
        $v_{\text{ind}} \leftarrow 1$        ▷ index of frames with $E_\ell^{(k)} = \overline{E}_\ell^{(k)}$
        for $k = 1, \dots, n$ do
            if $E_\ell^{(k)} = \overline{E}_\ell^{(k)}$ then
                $E_\ell^{(k)} \leftarrow E_\ell^{(k)} + v(v_{\text{ind}}) \cdot (B_\ell^{(0)} - S)$
                $v_{\text{ind}} \leftarrow v_{\text{ind}} + 1$
    $D_{\text{mean}} \leftarrow 1/n \sum_{k=1}^{n} f_{\text{FOP}}^{(k)}(\mathbf{E}^{(k)})$
$D_{\text{mean}}^{\star} \leftarrow D_{\text{mean}}$
```

## III. SIMULATION RESULTS AND ANALYSIS

In this section we numerically assess the influence of the system parameters on the distortion and lifetime of the network using simulation. We solved above Problem using the decomposition in EAP Algorithm as described in the previous sections for different scenarios. All cases envisage different groups of nodes placed at different locations.

***Distortion v/s Lifetime:*** In Figure 1, 2, 3 and 4 we plot the distortion v/s the lifetime obtained by solving the optimization problem for different values of n. We considered different values of the number of nodes ($N \in \{3, 15, 30\}$), uniformly distributed among the three groups, and a transmission average probability $Pr_{tx} \in \{0.2, 0.6\}$. The continuous lines represent the optimal solution described in above Section which explicitly accounts for the fading effects.

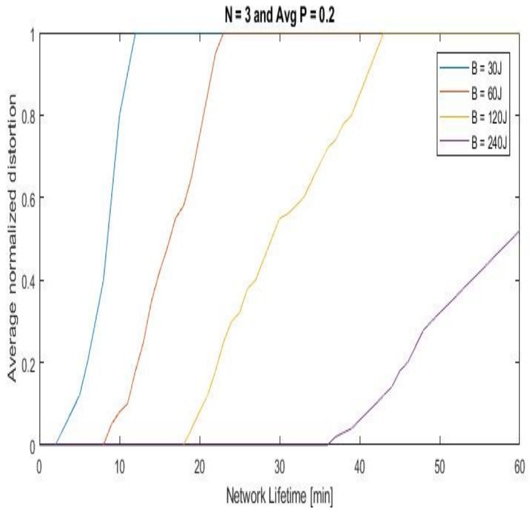

*Figure 1: Average normalized distortion as a function of the lifetime n with fading (N = 3 and Avg $Pr_{tx}$ = 0.2).*

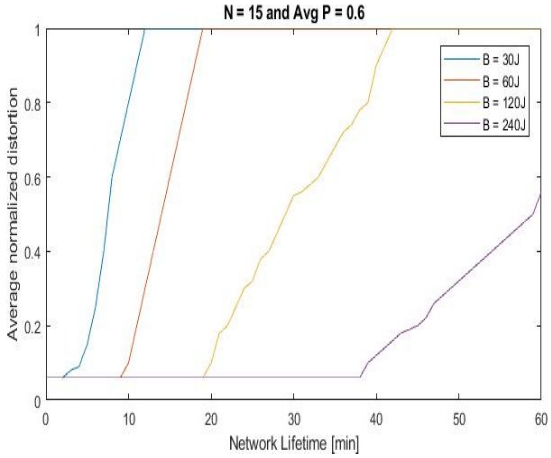

*Figure 2: Average normalized distortion as a function of the lifetime n with fading (N = 15 and Avg $Pr_{tx}$ = 0.6).*

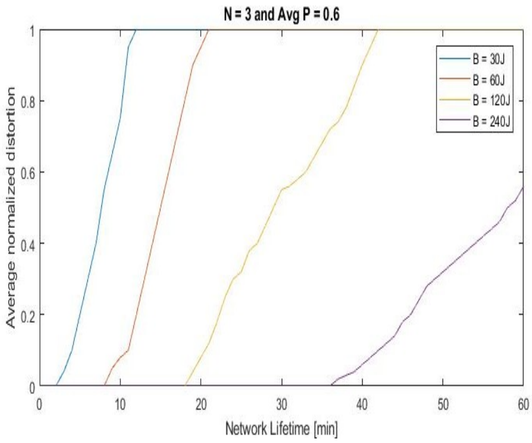

*Figure 3: Average normalized distortion as a function of the lifetime n with fading (N = 3 and Avg $Pr_{tx}$ = 0.6).*

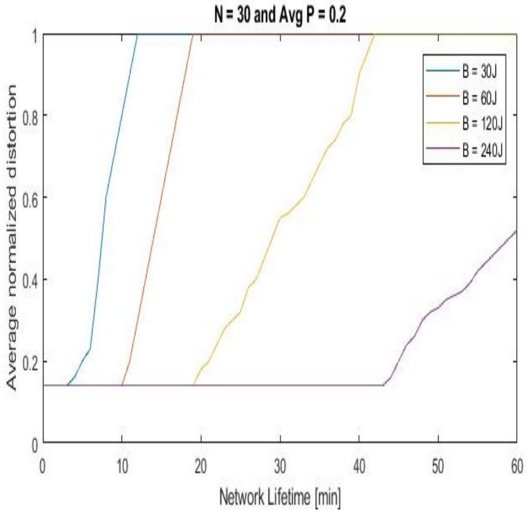

*Figure 4: Average normalized distortion as a function of the lifetime n with fading (N = 30 and Avg $Pr_{tx}$ = 0.2).*

The distortion tends to increase with the lifetime, as expected, since smaller amounts of energy can be allocated in each frame and thus nodes must compress high to transmit their information. For small values of n, the curves are maintains same because the target lifetime objective is reached even without depleting the batteries. In this case it is clearly shows possible to set the working point to the right extreme of the constant regions, as it yields the same Quality of service with large lifetime of nodes. Also, it can be noticed that the higher Average $Pr_{tx}$, the higher the distortion (i.e., the worse the performance); this happens because larger transmission probabilities impose to transmit more often even when the channel is in bad conditions.

## IV. CONCLUSION AND FUTURE WORK

In this paper, we presented a dynamic TDMA-based scheduling scheme that jointly considers energy consumption and data distortion. We studied the tradeoff between lifetime and distortion, and set up a framework that allocates the energy in every frame, determines the compression of the data to send along with the transmission durations, and performs power control and simulation results based on the characteristics of realistic devices was carried out to validate the analytical results and show that the approach with dynamic power control outperforms simpler schemes.

Future work includes the extension of the model to processing energy consumption functions that decrease with the compression ratio, the presence of rechargeable devices with EH capabilities, and the study of how the optimal solution is affected by latency in the coordination and control messages with the BS. It would also be interesting to analyze the effect of packet losses on the network performance when the Shannon limit on the channel capacity is not used, since they may have a strong impact on both the energy and the distortion metrics, and likely require a retransmission mechanism.

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