# RELIABILITY FOR A GREEN INTERNET OF THINGS

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**REZUMAT. Internetul obiectelor va schimba o gamă largă de aplicații de monitorizare în timp real, cum ar fi sistemul de sănătate, sistemul de automatizare, case inteligente, sistemul de monitorizare a transportului, mediului si automatizarile industriale. Referitor la domeniul sistemului de comunicații, în cazul în care sunt implicate un număr mare de dispozitive inteligente, prezentam in această lucrare potențialele bariere de fiabilitate pentru eficiența energetică, si propunem unele măsuri corective, exemple și tehnici. Acestea sunt utile în dezvoltarea și implementarea aplicațiilor IoT, pentru un oraș inteligent.**

**Cuvinte cheie:** IoT, IoT ecologic, eficiență energetica, rețea, obiecte.

**ABSTRACT. Internet Of Things is going to change a wide variety of real-time monitoring applications such as E-healthcare, homes automation system, environmental monitoring and industrial automation. As a innovation in the field of communication system where a big number of intelligent devices are involved, this paper discusses the potential Energy Efficiency Reliability barriers with suggested remedies, examples and techniques. Those are helpful in propelling the development and deployment of IoT applications for a smart city.**

***Keywords:*** *IoT, green IoT, energy efficiency, network, things.*

## 1. INTRODUCTION

**About SMART CITY concept.** With the rapid development of science and technology, the city is becoming "smart". Living in such a smart city, people will be automatically and collaboratively served by the smart devices (e.g., watches, mobile phones, different home appliances, computers), smart transportation (e.g., cars, buses, trains), smart environments (e.g., homes, offices, factories), etc. For example, using a global positioning system (GPS, AGPS, GLONASS), a person's location can be continuously uploaded to a server that instantly returns the best route to the person's travel destination, keeping the person from getting stuck in traffic. In addition, the audio sensor inside a person's mobile phone can automatically detect and send any abnormality in a person's voice to a server that compares the abnormality with a series of voiceprints to determine whether the person has some illness. Eventually, all aspects regarding people's cyber, physical, social and mental world will be interconnected and intelligent in smart city.

Our city is consisted of various „things". As one of the enablers of smart city, internet of things (IoT) targets to connect various objects with unique addresses, to enable them interacting with each other and with the world. Further, green IoT targets at a sustainable smart city, by reducing the energy consumption of IoT.

## 2. IOT AND GREEN IOT

The hot green information and communications technologies (ICT), green wireless sensor network (WSN), green machine to machine (M2M), green data center (DC), enabling green IoT.

## 2.1. IoT

We list two examples by ITU-T (International Telecommunication Union (ITU) Telecommunication Standardization Sector) and IERC (IoT European Research Cluster), respectively.

Definition of ITU-T: „In a broad perspective, the IoT can be perceived as a vision with technological and societal implications. From the perspective of technical standardization, IoT can be viewed as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies. Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, while maintaining the required privacy."

Defnition of IERC: „A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual „things“' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network."

### 2.1.1. IoT elements

Specifically, there are six elements in IoT:

**Identification -** electronic product codes (EPC), ubiquitous codes (uCode), etc.

**Sensing -** is can be humidity sensors, temperature sensors, wearable sensing devices, mobile phones, etc. Communication protocols available for the IoT are: Wi-Fi, Bluetooth, IEEE 802.15.4, Z-wave, LTE-Advanced, Near Field Communication (NFC), ultra-wide bandwidth (UWB), etc.

**Computation -** the hardware processing units (e.g., microcontrollers, microprocessors, system on chips (SoCs), field programmable gate arrays (FPGAs)) and software applications perform this task. Many hardware platforms (e.g., Arduino, UDOO, FriendlyARM, Intel Galileo, Raspberry PI, Gadgeteer) are developed and various software platforms (e.g., TinyOS, LiteOS, Riot OS) are utilized.

**Services -** in IoT can be categorized into four classes: identity-related services, information aggregation services, collaborative-aware services and ubiquitous services. Identity-related services lay the foundation for other types of services, since every application mapping real world objects into the virtual world needs to identify the objects first.

**Semantic -** means the ability to extract knowledge intelligently so as to provide the required services. This process usually includes: discovering resources, utilizing resources, modeling information, recognizing and analyzing data.

### 2.2. Green IoT

Since all devices in the smart world are supposed to be equipped with additional sensory and communication add-ons so that they can sense the world and communicate with each other, they will require more energy. These make green IoT which focuses on reducing the energy consumption of IoT a necessity, in terms of fulfilling the smart world with sustainability. Considering the energy efficiency as the key during the design and development of IoT, green IoT can be defined as follows [7]. „The energy efficient procedures (hardware or software) adopted by IoT either to facilitate reducing the greenhouse effect of existing applications and services or to reduce the impact of greenhouse effect of IoT itself. In the earlier case, the use of IoT will help reduce the greenhouse effect, whereas in the later case further optimization of IoT greenhouse footprint will be taken care. The entire life cycle of green IoT should focus on green design, green production, green utilization and _nally green disposal/recycling to have no or very small impact on the environment."

## 3. APPLICATION TYPES

**Smart Home**: Personal life-style at home is enhanced, by making it more convenient and easier to monitor and operate home appliances and systems (microwave, oven, airconditioner, heating systems, etc.) remotely.

**Industrial Automation**: With a minimal human involvement, robotic devices are computerized to finish manufacturing tasks. The machines' operations, functionalities, and productivity rates are automatically controlled and monitored.

**Smart Healthcare:** Performance of healthcare applications is improved, by embedding sensors and actuators in patients and their medicine for monitoring and tracking patients. For instance, by gathering and analyzing patients' body data with sensors and further delivering analyzed data to a processing center, the clinical care could monitor physiological statuses of patients in real-time and make suitable actions when necessary.

**Smart Grid**: Power suppliers are assisted to control and manage resources so that power can be offered proportionally to the city population growth. Therefore, the energy consumption of houses and buildings could be enhanced. For example, the meters of buildings could be connected to the network of energy providers. Then the energy providers could enhance their services, by collecting, analyzing, controlling, monitoring, and managing energy consumption.

**Smart City**: Quality of life in the city is ameliorated, by making it more convenient and easier for the residents to obtain information of interest. For instance, according to people's needs, various interconnected systems intelligently offer the desirable services (transportation, utilities, health, etc.) to people.

## 4. OVERVIEW OF IOT COMMUNICATION ARCHITECTURE

In figure 1, we can see that the architecture of Internet of Things consists of sensor nodes, application domains and network domain. In the node domain, the network is formed by a big number of IoT nodes {N0, N1 …} and an IoT Gate Way (GW). The IoT nodes are characterized by flexibility and real time monitoring technology. When the data is received the IoT nodes will make intelligent decisions and transmit the data packets to the Gate Way in different patterns. The Gate Way represents an integrated device. It manages to intelligently provide efficient paths for the received packets to reach the remote back-end server via wireless/wired networks. The network domain is providing cost-effective and reliable channels for sensory data packets to reach the application domain. Application domain represents the last part of the architecture. In this part, the back-end independent technical expert and consultant server is the key component. Here, all the data from the sensors is stored and provided in real time to a variety of IoT applications for remote monitoring management.

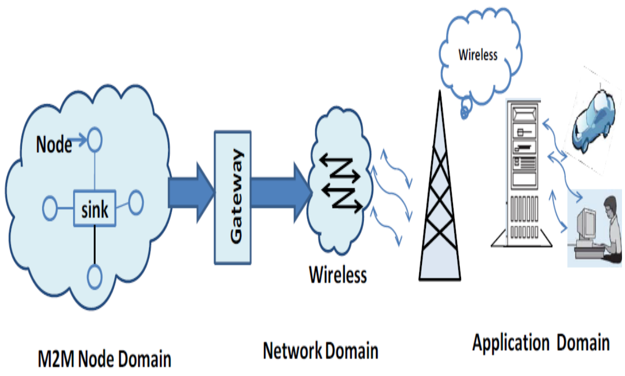


**Fig. 1.** Architecture of IOT.

## 5. ENERGY-EFFICIENCY AND RELIABILITY

Machine to Machine (M2M) communication is still facing many technical challenges, even if we have real-time applications and lots of benefits, M2M still needs improvement at: Architecture, independent technical expert and consultant been well exploited, the reports about global carbon emissions show us that information and communication technology is almost equal to the global aviation industry. The IoT communications are in a rapidly growing environment and they have the following common characteristics: a massive number of sensor nodes are deployed, real time-processes and the data is reaching the back-end server without direct human intervention. To have a successfully IoT communication systems in the next generation we need real-time monitoring applications and all the Energy-efficiency and Reliability requirements must be satisfied.

### 5.1. Eficiency

A mass of sensor nodes {N0, N1, …} are deployed in the IoT sensor domain, so the studies should focus on power saving by optimizing the sensibility, processing and transmission of the sensors. After all this the focus should move on raising the lifetime of the whole IoT communication. The back-end server is also a power consuming component in the IoT communication, so great efforts should also be made on it too, to achieve environment friendly green IoT communication

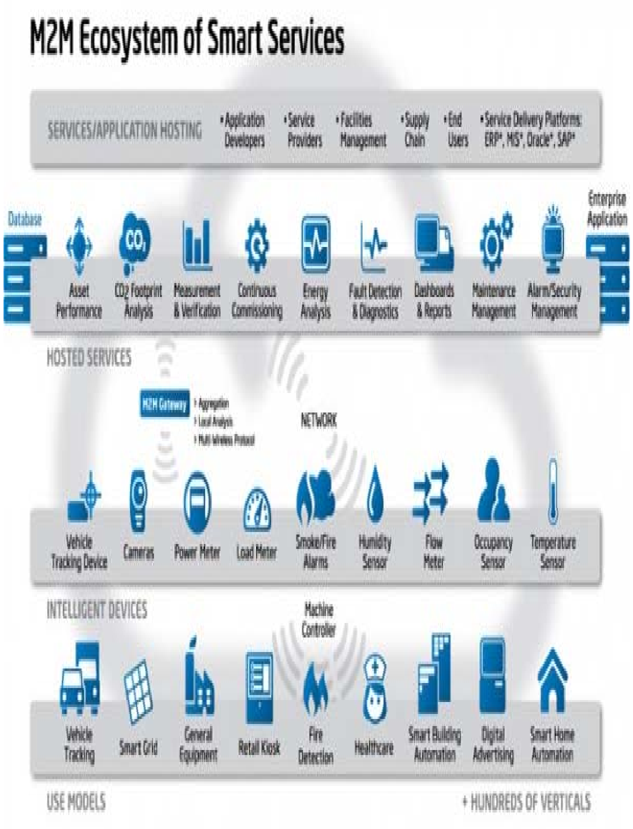


Fig.2. M2M Ecosystem of smart Services (Intel's M2M Ecosystem of Smart Services)

### 5.2. Reliability

A critical thing for Efficient IoT communications is Reliability, because an unreliable process of measuring could cause false monitoring data reports, data loss and long delays and this would reduce people's interest in IoT communication. The IoT communications are in a rapid grow process, so the reliability should improve even faster.

#### 5.2.1. Reliability in iot communication

Reliability is a challenging issue for achieving Green IoT, because not all sensor nodes are expected to simultaneously be active in IoT domain. Exploiting redundancy technologies, including temporal redundancy, spatial redundancy and information redundancy, can be an efficient approach for IoT communication.

*Tabelul 1.* **Different schemes and techniques for reliability in green IoT**

| Scheme | Techniques |
|---|---|
| Green RFID | 1) Reduce the sizes of RFID tags to decrease the amount of nondegradable material used in their manufacturing;<br>2) Energy-efficient algorithms and protocols for optimizing tag estimation, adjusting transmission power level dynamically, avoiding tag collision, avoiding overhearing, etc. |
| Green WSN | 1) Make sensor nodes only work when necessary, while spending the rest of their lifetime in a sleep mode;<br>2) Energy depletion (e.g., wireless charging, energy harvesting mechanisms which generate power from the environment (e.g., sun, kinetic energy, vibration, temperature differentials, etc.));<br>3) Radio optimization techniques (e.g., transmission power control, modulation optimization, cooperative communication, directional antennas, energy-efficient cognitive radio (CR));<br>4) Data reduction mechanisms (e.g., aggregation, adaptive sampling, compression, network coding);<br>5) Energy-efficient routing techniques (e.g., cluster architectures, energy as a routing metric, multipath routing, relay node placement, node mobility). |
| Green CC | 1) Adoption of hardware and software that decrease energy consumption;<br>2) Power-saving virtual machine (VM) techniques (e.g., VM consolidation, VM migration, VM placement, VM allocation);<br>3) Various energy-efficient resource allocation mechanisms (e.g., auction-based resource allocation, gossip-based resource allocation) and related task scheduling mechanisms;<br>4) Effective and accurate models and evaluation approaches regarding energy-saving policies;<br>5) Green CC schemes based on cloud supporting technologies (e.g., networks, communications, etc.). |
| Green M2M | 1) Intelligently adjust the transmission power (e.g., to the minimal necessary level);<br>2) Design efficient communication protocols (e.g., routing protocols) with the application of algorithmic and distributed computing techniques;<br>3) Activity scheduling, in which the objective is to switch some nodes to low-power operation ("sleeping") mode;<br>4) Joint energy-saving mechanisms (e.g., with overload protection and resources allocation);<br>5) Employ energy harvesting and the advantages (e.g., spectrum sensing, spectrum management, interference mitigation, power optimization) of CR. |
| Green DC | 1) Use renewable or green sources of energy (e.g., wind, water, solar energy, heat pumps, etc.);<br>2) Utilize efficient dynamic power-management technologies (e.g., Turboboost, vSphere);<br>3) Design more energy-efficient hardware (e.g., exploiting the advantages of DVFS (dynamic voltage and frequency scaling) techniques and VOVO (vary-on/vary-off) techniques));<br>4) Design novel energy-efficient data center architectures (e.g., nano data centers) to achieve power conservation;<br>5) Design energy-aware routing algorithms to consolidate traffic flows to a subset of the network and power off idle devices;<br>6) Construct effective and accurate data center power models;<br>7) Draw support from communication and computing techniques (e.g., optical communication, virtual machine migration, placement optimization, etc.). |
| General green ICT | 1) Turn off facilities that are not needed (e.g., sleep scheduling);<br>2) Send only data that are needed (e.g., predictive data delivery);<br>3) Minimize length of data path (e.g., routing schemes, network working mechanisms);<br>4) Minimize length of wireless data path (e.g., energy-efficient architectural designs, cooperative relaying);<br>5) Trade off processing for communications (e.g., data fusion, compressive sensing);<br>6) Advanced communication techniques (e.g., multiple-input multiple-output (MIMO), CR);<br>7) Renewable green power sources (e.g., oxygen, fresh water, solar energy, timber, biomass). |

### *5.2.2. Reliability in sensing and processing*

Because components have faults, a single IoT node is not sufficient to accurately sense and process monitoring data.

Therefore, in green IoT we need a "majority vote" to improve reliability. In a local vote decision fusion (LVDF) algorithm is presented, which can be applied directly in IoT communication. The LVDF works on a simple principle, each IoT node, first independently senses, processes and makes an initial single-bit decision (0 or 1) on some event in a specific IoT application and shares the decision with its neighbors. After receiving the responses from the neighbors, the node adjusts the initial decision based on the majority vote. Since LVDF is a corrected decision strategy, it can improve the processing reliability and the sensing in IoT communication by using additional information and temporal redundancy.

In Fig. 3 we use next terms: CSP (cloud service provider), CSU (cloud service user), SNP (sensor network providers).

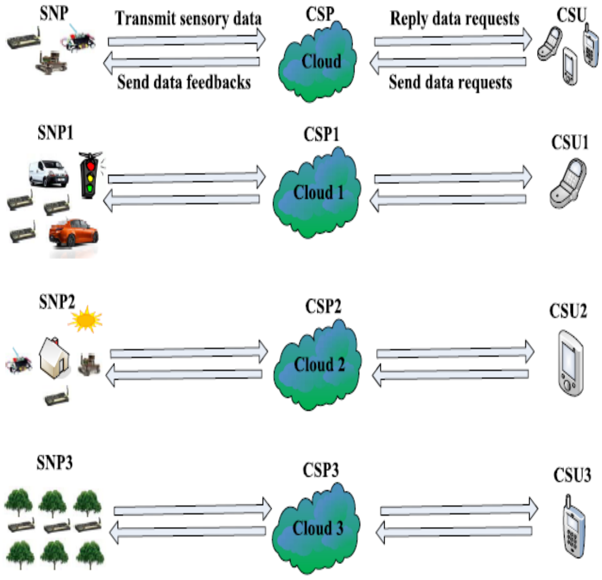


**Fig. 3.** Local vote decision fusion - LVDF algorithm.

### *5.2.3. Reliability in transmission*

If we consider a number of total positive monitoring data on the same event in the IoT domain, the Gate Way will report the decision to the back-end server only if it can collect more than another number of distinct monitoring data packets. These positive monitoring data first must be aggregated and then forwarded to the Gate Way together for achieving communication efficiency.

But in the case of Green Internet Of Things, not all nodes are active, which may lead to an unreliable transmission in the IoT domain. For the improvement of the reliability, the spatial redundancy can be adopted. This means that each monitoring data packet is independently transmitted to the Gate Way.

### *5.2.4. Reliability at back-end server*

The back end server receives sensory and decisional data packets from the Gate Way. Those packets are processed one by one in the application domain and only one server is used to process them as this saves power. But in peak hours, when almost or all the sensors are on load, one single server is not enough to deal with the situation. Therefore, this issue could be solved by introducing a pair of servers. So, when we reach the peak hour, the second server should start automatically.

### 5.3. Energy efficiency in IoT communication

The IoT communication is depending on the massive sensor nodes to intelligently collect monitoring data in the IoT domain, on the wired or wireless network to relay the collected sensory data to the back-end server and on the back-end server to support various IoT applications on the network in an application domain. Because a massive number of devices are involved the Energy Efficiency becomes a challenging issue especially in the IoT sensor domain.

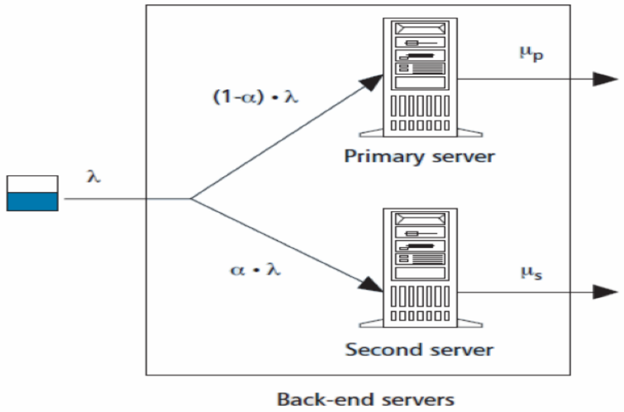


**Fig. 4.** Back-end servers.

The Energy Efficiency can be tweaked to higher levels by wisely adjusting transmission power to the minimal necessary level, creating algorithms and distributing computing techniques for efficient communication protocols. The activity scheduling can be a further improvement, for example to switch some nodes to low-power operation mode so that only some nodes remain active while the functionality of the original network is preserved. The scheduling requires time to be slotted and activity done in rounds. In each round a node selects a random timeout and listens to messages from neighbors before it expires. These messages contain the activity decision (ex: active or not) of their senders. The node decides to be active if the range is fully covered by the sensing ranges of a connected set of active neighbors. The scheme involves only local communication and a very small number of control messages, thus being Energy Efficient. After several simulations and tests based on ideal and realistic physical layers the scheme reveals the advantages over other similar algorithms. Therefore, the scheme can be applied to achieve Green communication in the IoT domain.

## 6. CONCLUSIONS

1. Special attention to sensor-cloud which is a novel paradigm in green IoT, the latest developments about sensor-cloud have been shown and the future sensor-cloud has been envisioned.

2. With this article we made an overview of the issues to achieve the green IoT communication by using efficient activity scheduling techniques for energy saving.

3. We also approached several reliability issues in IoT and EER issues, but further efforts are needed to identify the EER issues in specific IoT communication contexts.

**Few open problems:**

1) The design of green IoT, should be tacked from an overall system energy consumption perspective, subject to satisfying service objectives and achieving acceptable performance.

2) Realistic energy consumption models of different parts of IoT systems, are needed.

3) Investigate: a) energy effcient system architecture; b) energy effcient service composition strategies;

4) situation and context awareness regarding users and applications; d) energy efficient cloud management.

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