# Improvement of The Lifetime of Wireless Sensor Network State of the Art

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**Abstract**
*Thewirelesssensor networksare of considerable interestand a new stagein the evolution ofinformation technologyand communication. This new technologyis a growing interestgiven the diversityof these applications: health, environment,industry and evenin sports. Unlike traditionalnetworks, whichare concernedto ensure goodquality of service,wireless sensor networksmust, in addition, take into account theconservationof energy.They mustincorporate mechanismsthat allow usersto extend thelife of theentire network, since eachnodeis powered by alimited energy sourceand usuallyirreplaceable.In a sensornode, energy is consumedby providingthe following functions:capture,calculation(treatment)and communication.The latterrepresents a largeportionof the total energyconsumed.Therefore,the research communityis beingdeveloped and refinedseveral techniques forenergyconservation.Inthispaper, we presenta state of theartfor improvementthelifetime of wireless sensor networks.*

**Keywords:***Wireless sensor networks ; Energy efficiency; Power management ; sensor network lifetime ; energy Harvesting*

## I. Introduction

Sensor networksrefer towireless networksspontaneous(structure emerging from interactionbetween nodesaccording to the principlesof self-organization and self stabilization)dedicated to the observationof complex dynamicphenomena: Thesensor nodesaresmall autonomouselectronicdevices, battery powered andequipped withwirelesstransmission capacity(commonlyradiowaves), which will measurephysical quantitiesandcooperate topass the information, step by step, to acollection point.Sensor networkshave obviousadvantages:they can be deployedveryquickly, coververy largegeographical areasandoperate withouthuman interventionwith highfault tolerance.

Because of theirflexibility, low costand easeof deployment,wirelesssensor networkspromise to revolutionizeour livesthrough severalapplication areassuch assensing anddisaster monitoring, control of theenvironmentand mappingbiodiversity,intelligent building, precision agriculture, monitoring and preventive maintenance ofmachinery, medicine and health,logistics andintelligent transport.

Forlong-term monitoring, that is to sayfor networkswhoseexpected lifetimeisof the order ofseveral monthsor years, theconservation of energyis a fundamentalproblem given thatthe replacementbatterysensoris usuallyimpossible.The stressenergymotivatesmany of theresearch problemson networksofwireless sensors. La consommation d'énergie des capteurs joue donc un rôle important dans la durée de vie du réseau qui est devenue un critère de performance prédominant.

Several researchrevolvearound a commongoal: the identificationand characterizationof the mostenergyconsuming activitiesand optimizingthe energy consumption ofnodes-sensors. It is commonlyaccepted thatthe radio transmitter isone of the mostenergyintensive components[1] [2]. Thusmostofthe energy dissipated byasensornodefor the transmissionandthedata reception.

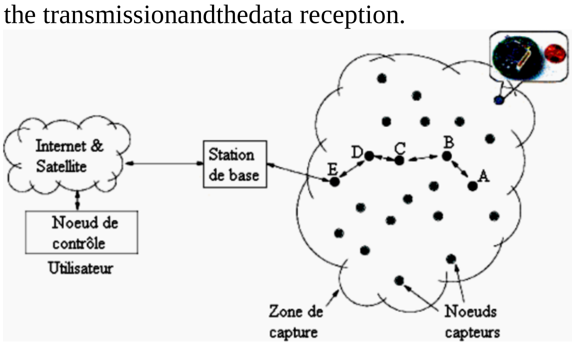



FIG.1.Sensor network architecture.

In this article our objective is to present a state of the art concerning improving the lifetime of wireless sensor network. The rest of this article is organized as follows: Section 2 briefly describes the various sources of energy in the external environment recovery. Section 3 presents the existing energy conservation techniques used in wireless sensor networks.

## II. HARVESTING ENERGY FROM THE EXTERNAL ENVIRONMENT

Theenergy sourceiseasier to usethe battery.In the caseof the sensornode in awireless sensornetworkthat solutionis unacceptable becauseitbecomesinactivewhen the batteryis exhausted. In other wordsto increasethe autonomy of thesensornode, it isnecessary to increase thesize of the battery, which is inconsistentwiththe authority toautonomousmicrosystemintegration.The solution thenisto use rechargeableenergy reservoirsornamed assecondarybatteries. Themost common sidetanks arerechargeablebatteries.Currentlyconsiderable effortsin this area aremade toco-integrate these energysources.Thesehighenergytanksneed aprimary energy sourceforrecharging.In the following wewill brieflypresent someprimary energy sources.

**A. SOLAR ENERGY**

Systems usingsolar andlight energyare most commonlyregardedas a source ofenergy recovery.Photovoltaic cellsoffer excellentpower densityin adirect exposure tosunlight.The light energyavailable insideishoweversignificantly reduced.[3].

**B. ELECTROMAGNETIC WAVE**

Another approachis to harvestthe powerof propagation ofRFsignals (radio frequency) emitted by strong electromagneticfieldssuch astelevision signals,thecell phone towersandradio waveswireless networks(GSM,Wi-Fi).TheRFenergy can beextracted from the airandconvertedinto a DC voltageusablebyaconverting circuitincorporated in apowerreception antenna. However, the levelofrecoverable powerislimitedbecause theRFenergyspreadrapidly decreasesas thedistancefrom the source increases.

*C. THERMAL ENERGY*

Thetemperature gradients existingin natureand the human bodyhasthe capacity togenerate electricity. The most basicthermoelectric generatorcomprises athermocoupleconsistingoftwodifferentblocksconnected bya metal stripmaterial. The temperature differencebetween the lower partandthe upper partof the legsresults inan electrical current(Seebeck effect). Generally, the jambes are made of highly doped semiconductor p and n type for better performance, combining good electrical conduction and heat resistance (to keep the temperature gradient). Practically, athermoelectric energyrecoveryisthermopilethatis constitutedofmanythermocouplesconnected electrically inseriesandthermallyin parallel.Mostresearch focuseson the optimization ofnanostructuredthermoelectric materialsand their geometryto produceenough power andvoltagefromtemperature differencesas reduced of5-10 ° C. One challenge isto maintainthe temperature gradientbetween the hotand coldsmall scaleregion, includingwhen usedon the human body [4].

**D. L'ÉNERGIE MÉCANIQUE**

One method ofharvestingthe most effectiveenergyis to convertmechanical energy frommovement orvibrationsinto electricalenergy using, for example, electromagnetictransducers,piezoelectricorelectrostatic . Conversion istwomechanisms: direct applicationof force andthe useof the inertiaacting onamassforces.

Electromagnetictransducersare difficult tominiaturize, tohaveamicroscopic scaleofvery highimpedanceloadandgenerate onlylow voltages.Electrostaticgeneratorsrequire for theirshareof a potentialapplicationon startup anddeliveralow power density, but they have the advantage of beingmore easily integratedwithCMOStechnology(Complementary MetalOxide Semiconductor).

Piezoelectric recuperators have in turn the advantage of greater power density generated in a small scale [3].

## III. ENERGY CONSERVATION SCHEMES

Experimental measurementshave shown that, generally, it is the transmissiondatawhich is the mostenergyconsuming, andsignificantly, the calculations, theyconsumeverylittle [5]. Theenergyconsumptionof the detection moduledepends on the specificityof the sensor. In many cases, itis negligible comparedto the energy consumedbythe processing moduleand, above all, the communication module. In other cases, the energy usedfor the detectioncan be comparableorgreater than thatrequired for the transmissionofdata. In general,energysaving techniquesfocuson two parts :the network portion(ie,power managementisreflected inthe operations of eachnode, as well as in the design ofnetworkprotocols), and the detectionpart (ie, techniques are used to reducethenumber or frequencysamplingtheenergycost). The lifetimeof asensor networkmay be extendedby the combinedapplication of differenttechniques [6].

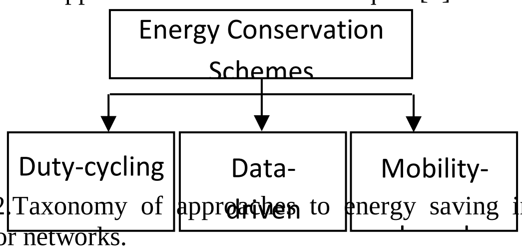
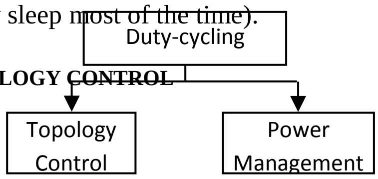



FIG.2 Taxonomy of approaches to energy saving in sensor networks.

**III.1. DUTY-CYCLING APPROACHE**

This techniqueis mainly used innetwork activity. The most effectivewayto conserve energyis toturn the radiotransmitterin(low-power) standby modewheneverthecommunicationis not necessary. Ideally, theradiomust be turned offas soon as itis no moredata to sendandor receive, and should be readyas soon as anew data packetto be sent orreceived. Thus, the nodes alternate betweenactiveandsleepperiodsbased onnetwork activity. This behavior is usuallyreferred to asDuty-cycling. Aduty-cycle isdefined as thefractionof time thatthe nodesare active.Asnodes-sensors performtasks in cooperation, they must coordinate theirdatesof sleep andwaking. ASleep /Wakescheduling algorithmthereforeaccompany anyplanDuty-cycling. This is usuallya distributedalgorithmbased onthe dates on whichnodesdecide toswitch betweenthe active stateandsleepstate. It allowsneighborsto besimultaneously activenodes, which enables the exchangeof packets,evenif the nodeshave a lowduty-cycle (ie, they sleep most of the time).




**III.1.1. TOPOLOGY CONTROL**

The topology control is to eliminate unnecessary network nodes (in the sleep redundant nodes) and links unnecessary (by adjusting the power of the radio transmitter, and therefore the scope of the communication) to reduce the energy consumption in the network. It istherefore toareduction of the initialnetwork topologywhile preservingthe coverage ofthe area of interestandnetwork connectivity[7]. This reducedtopology mustbekept updatedfrom time to timebecause thenetwork needsto evolveasthatof the active nodesare dying. Thepower controlon the radio transmitterhas notonlyan effect onthelife ofthebatteryof the nodes, butalsoonthecapacity of thetraffic. The control moduleof the power isoftenincorporatedin the protocolsofthenetworkoreitheroftheMAClayer. In [8], the authors demonstrate that there is an optimal scope of radio signal which minimizes the energy dissipated while maintaining connectivity. When the array of sensors is particularly dense, it is desirable to limit the closest neighborhood nodes to reduce collisions. in this optical, several algorithms topology control exist, especially DURING and DLMST that build the topology reduced based on the collected information locally.

With DLST [9] (Directed Local Spanning Subgraph), each node knows its position and that of its neighbors in one hop. Each node computes a minimum local spanning tree from its direct neighbors. The construction of the topology is based on the local node of each tree. with DRNG [9] (Directed Relative Neighbor- hood Grapheach sensor knows its position and distribute to its immediate neighborhood. With the position of its 1-hop neighbors, a node will deselect the longest links.

#### III.1.2. POWER MANAGEMENT

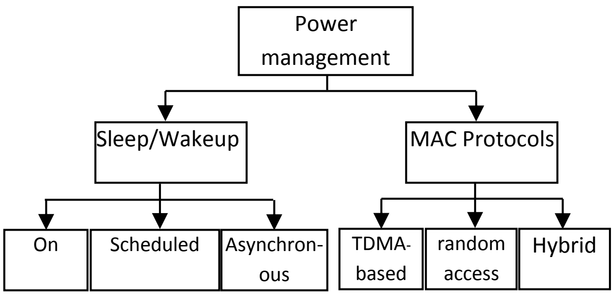



FIG.4.Classification of power management techniques

#### A. PROTOCOLES VEILLE-SOMMEIL (SLEEP/WAKEUP)

As mentioned earlier, a system sleep / wakeup can be defined for a given component (ie the Radio module) of sensor node. We can meet the principal planes sleep / wake up established as independent protocols above the MAC protocol (ie at the network layer and the application layer). Protocols sleep / wakeup are divided into three broad categories: on-demand, scheduled Rendezvous, asynchronous systems.

- ***Protocols on demand*** use the most intuitive approach to power management. The basic idea is that a node should wake up only when another node wants to communicate with him. The main problem associated with diets demand is how Tell a dormant node another node is willing to communicate with him. To this effet, these systems generally use multiple radios with different trade-offs between energy and performance (ie a radio at low rate and low power for the lights, and a radio "up" rate but in higher consumption for data communication). The protocol STEM (Sparse Topology and Energy Management) [10], for exemple, uses two radios ;
- Another solution is to use an approach to ***scheduled rendezvous***. The idea is that each node has to wake up at the same time as its neighbors. Typically, nodes wake up following a schedule of waking and remain active for a short period of time to communicate with their neighbors. Then they go back to sleep until the next *rendezvous*;
- Finally, a sleep/wakeup asynchronous protocol can be used. With asynchronous protocols, a node can wake up when they want and as long as he is able to communicate with its neighbors. This object is achieved by the properties involved in the sleep/wakeup scheme, no exchange of information is then required between nodes. Some diets sleep/wakeup asynchronous proposed in [11].

#### B. MAC PROTOCOLS WITH LOW DUTY CYCLE (MEDIUM ACCESS CONTROL)

Several MAC protocols for wireless sensor networks have been proposed, and many states of the art and introductions to the MAC protocols are available in the literature (eg [12]). We mainly focus on issues of power management rather than the channel access methods. Most of them are implementing a plan with a low duty-cycle to manage energy consumption. We have identified the most common MAC protocols by classifying into three categories : TDMA-based MAC protocols Contention-based protocols and hybrid protocols.

#### B.1. TDMA-BASED MAC PROTOCOLS (TIME DIVISION MULTIPLE ACCESS)

In theMACprotocol basedontime divisionmultiple access(TDMA) [13], each node hasa timewhere he canaccess the channeland usingall the bandwidthallocatedby the sensorfor transmission.TRAMA[14] is among thefirst techniques oftraffic management intheprotocolbased onTDMAnetwork. TRAMA, based on a distributed algorithm, provides a dynamic allocation of time slots within two hops. The access time to the channel is divided into two periods. In the first access period, the nodes exchange the addresses of neighbors for having a topology of all the neighbors located to two hops while in the second period the time is divided into several time intervals.

*B.2. RANDOM ACCESS MAC PROTOCOLS*

Random access means that all nodes share the transmission channel have the same right of access to it. This solution allows adaptability vis-à-vis the density and changes in network topology. However, it is also subject to access conflicts that lead to collisions and hence packet loss during transmission and energy at the MAC layer. CSMA and CSMA / CA. The multiple access with listening with carrier(CSMA for Carrier Sense Multiple Access) is introduced by (Kleinrock and Tobagi 1975).

In CSMA a node wishing to transmit a message, listen to the channel to determine if it is occupied. In this case, the node waits a random time before attempting retransmission. When the channelbecomes free, the node transmitsthe message immediately. An extended version of CSMA with Collision Avoidance CSMA / CA (CSMA / CA for CSMA Collision Avoidance) was proposed. She adds mechanisms to limit the number of message loss when neighboring nodes transmit at the same time. Wireless networks avoid collisions by exchanging control messages to reserve the channel before each data transmission.

The authorsin [15] proposed the MacprotocolS-MAC (SensorMAC). The main idea ofthis protocol is todivide the timeof the sensorinto two parts:activeandsleep. When the sensor gets activated, the sensor is ready to transmit or receive data while in the sleeping state, the sensor can neither transmit neither receive data. However, it is impossible to change the active and sleeping time after sensor deployment which prevents the sensors to adapt to different levels of traffic. It is for this reason that the authors in [16] proposed T-MAC (MAC Timeout).

In T-MAC, nodes are synchronized to get into active mode and sleeping periodically like S-MAC. However,thetime interval in T-MAC is not fixed by the application, but varies according to network traffic. If traffic is important, the sensors remain longer in active mode to transmit more data and if traffic is light, the sensors remain active shortest time to save energy. Alwaysbased on the methodofsettingactive mode andsleepperiodicallysensors, D-MAC [17] provides a verylow latencywhen comparedwith otherMACprotocolsin the samefamily. The purpose of D-MAC is that all nodes included in the multi-hop path to the sink are in active mode when data is being sent.

**B.3. HYBRID MAC PROTOCOLS**

A third family of protocols proposes to combine the two methods:

CSMA and TDMA. Thus, these protocols are trying to have the advantages of both methods by alternating the two in time or by combining them intelligently.

Z-MAC (Zebra-MAC) [18] dynamically changing transmission mode between CSMA and TDMA based on the current network load. Z-MAC uses CSMA as a basic protocol for media access but uses a TDMA scheduling to improve the resolution of contention between nodes. Crankshaft[19] is a hybridMACprotocol.In this protocol, time is divided into framesandeach frame is composedofseveralslots. To receive data, each node selects a unicast slot and all slots of broadcast during which he listens to the channel. Ainsi, thus Crankshaft, ordinance the data reception rather than sending. Funneling-MAC [20] is a hybrid MAC protocol that deals with the problem of congestion and packet loss observed by nodes near of the well. The protocol uses TDMA in this region and CSMA elsewhere. TDMA is managed by the well. All nodes use CSMA by default, unless they receive a message of the well informing them should use TDMA.

**III.2. DATA-DRIVEN TECHNIQUE**

the data-driven technique in wireless sensor networks aims to reduce the amount of data to be processed and transmitted. This technique can be classified according to the stages of data processing, into three categories: data acquisition, processing and transmission.

**III.2.1. DATA ACQUISITION**

Some physical magnitudes measured by the sensors do not change between two samples, it is the case for example where a temperature measurement où la dynamique est lente. This has encourage researchers to exploit the temporal correlation of the data. Techniques based on the collection of data can be classified into two categories: technique based on the prediction and techniques based on sampling.

– ***Technique based on a data forecast*** : A model of forecasting is established during the sampling data, so that future values can be predicted with some accuracy. This approach exploits the model obtained for reducing the number of acquired data, and also the amount of data to be transmitted to the well.

An example of the forecasting technique centralized been proposed in [21]. The authors proposeda prediction modelforenvironmentalmonitoring applicationsnamed "PREMON" which is based on twoprinciples.The firstis to exploitspatial correlations. Recognizing the efforts of a sensor, it becomes unnecessary for a neighbor to retransmit all packets received but only the relevant changes.

The second is based on the fact that an preview of network may be considered an image and therefore the evolution of the measurements can be viewed as a video.

By exploringthe concept ofMPEG,PREMONgenerates aprediction modelin the well andsentperiodically to thesensor nodes. Indeed, afterdeployment,thesensor nodessend theirinitial actionsat the well.

then the well then calculates the predictive model by exploiting the correlations between the data and sends it to the sensor nodes. Thus, upon receiving the model, the sensor node compares its data with the estimated value of the forecasting model. If the two values are close, the sensor node does not transmit its measurement at the well. (Vuran and Akyildiz, 2006) proposed a technique reducing the number of transmissions. The idea is to use the spatial correlation among a dense set of nodes to reduce the number of nodes relaying the event. It thus limits the number of collisions, improves transit time and saves energy. In [23], a prediction model based on clustering was proposed named ASAP. The authors of ASAP propose to regroup sensor nodes that have the same measures in the same cluster. The cluster-head and the well maintains the forecast model. And measures only above a certain threshold are transmitted to the well. The protocol "buddy" presented by [22], is based on the same principle as PREMON but using a distributed scheme to exploit the correlations between data. In the "buddy" protocol, sensor nodes are grouped together to form clusters and in each cluster, one node is chosen to represent the group.

– ***Technique based on the sampling*** : Techniques based on sampling can be classified into three categories: Adaptive sampling, hierarchical sampling and active sampling based on a model. As measured samples can be correlated, the adaptive sampling techniques exploit these similarities to reduce the number of acquisition.

The hierarchical sampling approach assumes that the nodes are equipped with sensors (or detectors) of various types. As each sensor is characterized by a given resolution and associated energy consumption, this technique dynamically selects the class to turn to obtain a compromise between precision and energy saving. The active sampling based on a model adopts a similar approach to forecasting data. A model of the phenomenon being measured is established during the sampling data, so that future values can be predicted with some accuracy. This approach exploits the resulting model to reduce the number of data samples, and also the amount of data to be transmitted to the well, although this is not their main goal.

*III.2.2. PROCESSING AND DATA TRANSMISSION*

Several approaches to data processing have been proposed in the literature to address the problem of energy conservation in wireless sensors. We present the main two. The first is based on data compression and the second on the aggregation of data.[24]

– ***Data Compression*** **:** The critical parameter networks of wireless sensors is their lifetime. But which are costly energy is communications. The advantage of the methods of compression is to allow less data to communicate, and thus to save energy, which results in an elongation of the life of the networks. However, compression algorithms commonly used on computer (such as Lempel-Ziv, WinZip or JPEG) are not directly transferable to all sensors, as many assume too many calculations in comparison to the gain provided. There are several methods of data compression. The main compression methods suited to wireless sensor networks data are:

– ***The coding by scheduling*****:** Compression in coding by scheduling is to remove redundant information from the sensors (the destination address, control code errors, clock synchronization) and merge the remaining data. Thus, the number of packets sent is reduced. In coding by scheduling, nodes send their packets to a single node called « node compression ». The encoded packet is constructed from combinations of the packets received from several nodes. The protocol "Funning" [25], based on the scheduling approach considerably reduces the amount of energy consumed during communication of up to 44% energy saving. This objective can be achieved by only sending a single data stream to a group of sensors instead of each individual sensor sends its data.

– ***the compression distributed***[28] **:** Each sensor provides a binary representation of its samples taking into account the correlation with the samples measured by the other sensors. Communication between sensors is forbidden which makes the estimation of this correlation difficult in practice.

– ***data agrégation*** : Sensor networks are dense enough in general, this means that nodes close enough (neighbors) can capture the same data (temperature, pressure, moisture equivalent, for example). Therefore, several studies have been conducted to eliminate redundancy and reduce data traffic in the network. The mechanism consists in treating the data collected by each sensor in a node called « aggregator node ». Only the result produced will be transmitted to the base station. In this way, the amount of data communicated in the network can be reduced, which consequently reduces the consumption of bandwidth and depletion of sensors energy.

The data aggregation techniques can be divided into two:

– ***centralized aggregation*****:** Aggregation in the clusters, formed via a clustering protocol. First zones (clusters) are defined via a protocol then the data are aggregated in these areas through a cluster-head. the latter may may possibly change over time in order to better distribute energy consumption among all nodes in the network.

– ***distributed aggregation*** **:** Aggregation is distributed in an aggregation tree that is to say that the network is viewed as a whole. COUGARprotocol[26] is an example of aggregationofdistributed data. The data producedby the networkare modeled asa relational table,the network isseen asa largedistributed database.The attributesof thistableare eithersensor informationor dataproduced bythe sensorbecauseCOUGARprovides partialaggregationat nodes.

**III.3. MOBILITY TECHNIQUE**

In some cases where nodes are mobile, mobility can be used as a tool for reducing energy consumption (beyond the duty-cycling and data-driven techniques). In astaticnetworkofsensors, packets fromnodesfollowmultihoppaths tothe base station. Thus, some paths can be loaded (solicited more than others), and the nodes nearby to the base station relaying more the packets and are more prone to premature depletion of their batteries (funneling effect). If some nodes (possibly the base station) are mobile, traffic can be changed if the mobile nodes are responsible for collecting data directly from static nodes. Ordinary nodes are waiting for the passage of a mobile device to send their messages so that communication takes place nearby (directly or at most a limited number of hops). Therefore, ordinary nodes can save energy because the path length, contention and overheads of diffusion are thus reduced. In addition, the mobile device can visit the network to evenly distribute uniformly the energy consumption due to communication. When the cost of the mobility of sensor nodes is prohibitive, the traditional approach is to attach a sensor to entities that are roaming in the sensing field, such as buses or animals. Strategies based on mobility can be classified into two groups: strategies with a mobile Sink and strategies with mobile relays, depending on the type of the mobile entity. It is important to note here that when we examine mobile systems, an important problem is the type of control the mobility of nodes that Integra network design, this is detailed in [27]. Mobile nodes can be divided into two categories: they can be specifically designed as part of the network infrastructure, or part of the environment. When theyare part of theinfrastructure, mobility can be fullycontrolledto the extent thattheyare generallyrobotic. Whenmobile nodesare part ofthe environment, theymay notbecontrollable. If they follow a strict schedule, they have a completely predictable mobility (eg, a shuttle for public transport). Otherwise, they may have a randombehaviorsuch that noassumptioncanbe madeontheirmobility. Finally, they can follow a pattern of movement, which is neither predictable nor completely random. For example, in the case of a bus moving in a city whose rate is subject to significant variation due to traffic conditions. In this case, the mobility patterns can be drawn based on observations and estimates of some precision.

## VI. CONCLUSION

In this article, we presented a state of the art works found in the literature, which deal mainly improving the lifetime of a network of wireless sensors. We presented first in a brief manner the different sources of energy recovery in the external environment such as solar energy, electromagnetic waves and thermal energy. In the remainder of this paper we describe the different approaches to existing energy conservation used to extend the lifetime of a network of wireless sensors. To this end, several methods have been developed either as MAC protocols, low duty-cycle or as independent higher level protocols based on scheduling sleep / wakeup and there are other methods that is interested in data acquisition and processing and transmission of data and methods that use the technique of node mobility. There are of course many other techniques of energy conservation. For example, from paradigms of self-organizing systems, cross-layers and other mechanisms independent network protocol level or application level.

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