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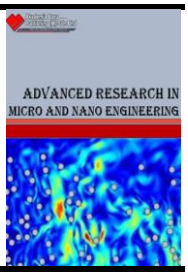

A Comprehensive Systematic Review: Sleep Strategy on Microcontroller for Power Management

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ABSTRACT

Since microcontrollers are used in so many modern electronics, power management has become an important part of making sure they work well and last a long time. This systematic study carefully looks at all the different sleep strategies that can be used on microcontrollers to manage power. By putting together, a lot of different pieces of literature, the study aims to give a full picture of the different approaches, problems, and progress made in using sleep strategies to make microcontroller-based systems use less power. The review uses a structured and organized method to find applicable studies, look at their methods, and pick out the most important results. It sorts sleep techniques into groups based on how they work, what they're used for, and how complicated they are. It is important to find similarities and differences between studies so that we can see what's new in microcontroller power management through sleep techniques. Some of the main topics that were looked at were how sleep strategies affect total power use, the trade-offs between saving power and reducing latency, and new trends in the field.

1. Introduction

The emergence of microcontroller technology has inaugurated an age of supreme creativity and amalgamation across multiple spheres of engineering and technology. Microcontrollers, serving as the essential building blocks of embedded systems, have attained omnipresence in contemporary society. They oversee the operation of devices and systems spanning from everyday household appliances to intricate industrial machinery. Nonetheless, these tiny computational powerhouses frequently contend with restricted energy reservoirs, rendering power management a fundamental consideration in their functionality [1-5]. Implementing efficient sleep techniques is a crucial part of power management in microcontroller systems. A variety of methods are included in sleep tactics with the goal of decreasing power use during periods of inactivity while assuring rapid and effective reactivation when necessary. These tactics are crucial because they have a direct impact on the

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operational lifespan, energy efficiency, and general performance of applications based on microcontrollers [6,7].

The development of microcontroller sleep techniques has seen a recent uptick in research and development due to the desire for improved energy efficiency and longer battery life. To optimize the power consumption patterns of microcontrollers during the sleep and wake stages, researchers, engineers, and business professionals have investigated a variety of approaches, algorithms, and hardware designs. Due to the abundance of research results, a thorough and systematic study is required to compile and assess the most advanced sleep techniques used in microcontroller systems [8,9]. With a thorough and organized analysis of the available literature, this study sets out on a journey into the world of microcontroller sleep methods. The goal is to offer a comprehensive overview of the various strategies, techniques, and breakthroughs that have surfaced in the field of microcontroller power management. The goal is to highlight the advantages, disadvantages, and prospective directions for further research in this important area by synthesizing the collective knowledge of the scientific community. This systematic review will explore the subtleties of microcontroller sleep modes, the function of software and hardware in power consumption optimization, and the practical applications that gain from effective sleep techniques. Additionally, this study will carefully examine the trade-offs between energy efficiency and system responsiveness while considering the dynamic needs of modern embedded systems.

2. Methodology

A significant ongoing global discourse revolves around the topic of systematic evaluations. Unfortunately, the research conducted on the overview of sleep strategy on microcontrollers is constrained to a restricted number of studies [10]. The subsequent part provides a description of the methodology employed to address the research inquiries posed by prior studies. The primary objectives of this study are to examine and comprehensively examine the sleep technique employed in microcontrollers across five specific areas of implementation: (1) wake up radio, (2) small-cell networks, (3) Wireless Sensor Network (WSN), (4) microcontroller and (5) others applications. One additional purpose is to examine the comprehensive frequency of occurrence and the corresponding management strategies. Subsequently, this section undertakes a comprehensive examination and integration of scholarly literature with the aim of identifying, selecting, and evaluating noteworthy studies pertaining to cervical cancer. Finally, our objective was to propose other areas of investigation in light of the aforementioned difficulties outlined in this paper. This research used the pre-recording systematic reviews and meta-analysis (PRISMA) technique, which is a well recognized and acknowledged standard for conducting systematic literature reviews. The primary purpose of publication guidelines is to aid authors in assessing the accuracy of a critique by furnishing essential and obligatory information. The inclusion of randomized investigation assessment surveys in systematic analysis reports across many forms of research is emphasized by PRISMA [11]. The technique of this research was examined using two databases, namely Web of Science (WoS) and Scopus, because of their robustness. Nevertheless, it is important to note that even widely used databases such as Scopus and WoS are not exhaustive and comprehensive in their coverage. This part also includes a discussion of the four main sub-sections, namely identification, screening, eligibility, and data abstraction.

2.1 Identification

Several relevant publications were selected for this study using a systematic review technique, which includes three main parts. The first step uses thesauruses, dictionaries, encyclopedias and previous research to identify keywords and search for related terms. After selecting all relevant terms, search strings were generated for Scopus and Web of Science databases (see Table 1). In the initial phase of the systematic review procedure, the ongoing research project managed to find articles from both databases.

2.2 Screening

The collection of possibly relevant research items is examined for content that matches the established research article(s) during the screening stage. The list of documents to be searched in this stage will be purged of any duplicate papers. According to numerous inclusion and exclusion criteria for this study, 53 papers were evaluated in the second stage of the screening procedure, while 137 publications were disqualified in the first stage (see Table 2). The primary source of helpful information, literature (research articles), was the first criterion used. The list only includes articles that were left out of the most recent study. Furthermore, only English-language articles were included in the review. It is important to remember that the strategy was restricted to the years 2019 to 2023.

Table 1
The search strings

Scopus	TITLE-ABS-KEY ("sleep strategy" OR "wake up" AND microcontroller) AND (LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023)) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))
WOS	"sleep strategy" OR "wake up" AND microcontroller (All Fields) and 2023 or 2022 or 2021 or 2020 or 2019 (Publication Years) and Article (Document Types) and English (Languages)

2.3 Eligibility

The third level, called eligibility, contains a total of 41 items. At this point, all article titles and significant material were closely examined to ensure that the inclusion criteria were met and the articles were relevant to the goals of the current study's research. Due to their exclusion from the area, lack of full text access based on empirical data, and lack of relevance to the study's purpose, 13 papers had their titles and abstracts removed. Last but not least, 28 papers have been made available for evaluation (see Table 2).

Table 2
The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line	2019 – 2023	< 2019
Document type	Article	Review, Conference

2.4 Data Abstraction and Analysis

In this study, an integrative analysis was employed as one of the assessment strategies to examine and synthesize numerous research designs (quantitative methods). The goal of the expert study was to identify relevant topics and subtopics. The data collecting stage was the initial step in the theme's development. As depicted in Figure 1, the authors meticulously analyzed a compilation of 28 publications for assertions or material relevant to the present study's topics. The authors next assess power optimization on microcontroller-based Internet of Things throughout the identifying and establishing significant groupings in the second stage.

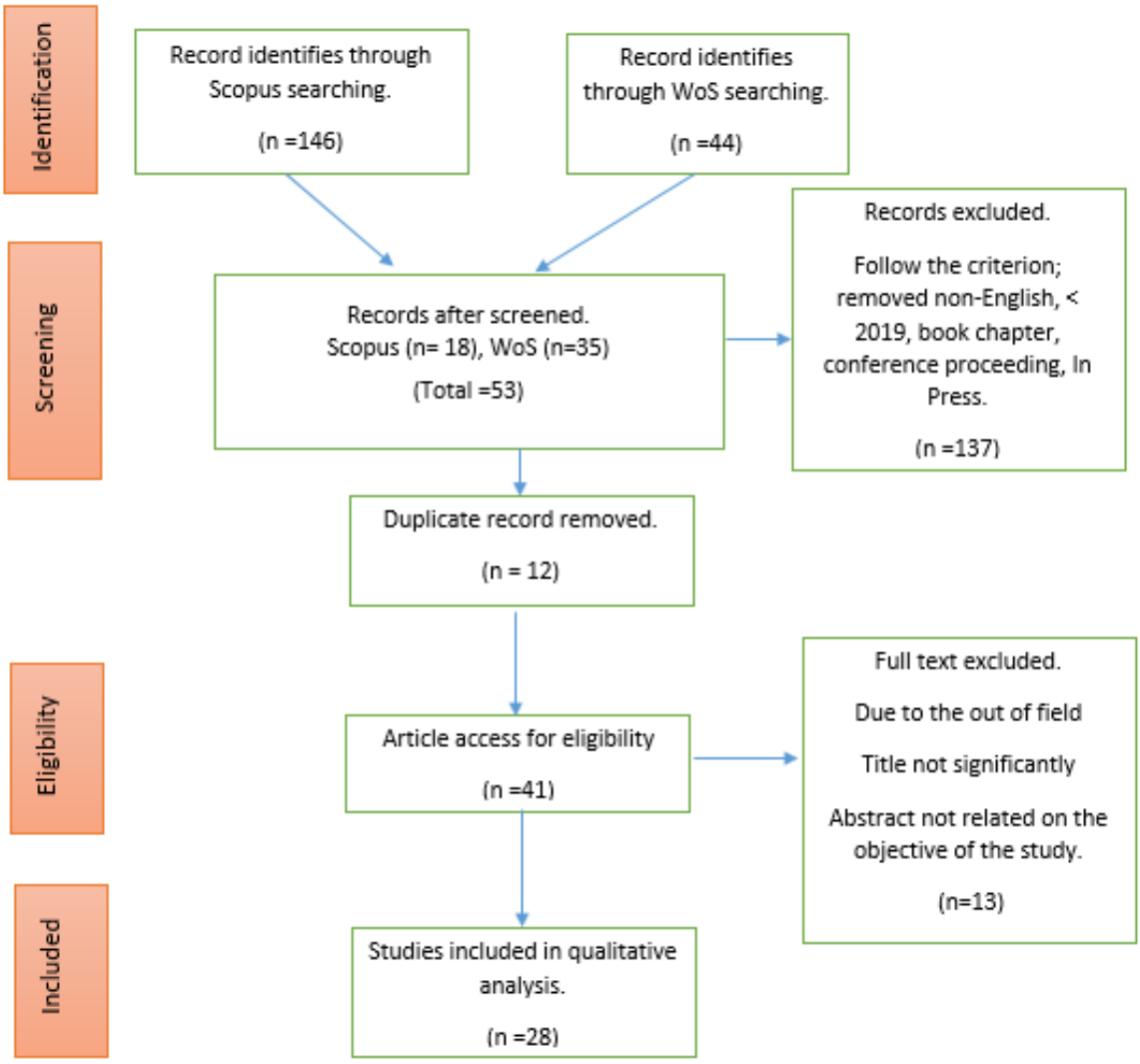

Fig. 1. Flow diagram of the proposed searching study

3. Results

A total of one hundred ninety published studies have been identified using a comprehensive search. After excluding studies that did not meet the eligibility criteria, a total of twenty eight studies were included in this study. Subsequently, the ultimate collection is partitioned into five distinct domains of implementation, namely: (1) wake up radio, (2) small-cell networks, (3) Wireless Sensor Network (WSN), (4) microcontroller and (5) other applications.

3.1 Wake Up Radio

The inclusion of sleep mode in Wake-Up Radio (WUR) applications is of utmost importance, as it allows devices to transition into a state of reduced power consumption while still retaining the capability to awaken in response to designated signals or events. The capacity to remain in a low-power state for extended periods and activate only when necessary is crucial for energy conservation in battery-operated Internet of Things (IoT) devices [12].

According to Ba *et al.,* [13], the utilization of passive wake-up radios that employ radio wake-up techniques has the potential to minimize overhead and enhance energy efficiency in wake-up radio (WUR) applications. Larsen [14] has conducted research on the development of advanced sleep-mode algorithms to optimize battery life in real-time situations.

In the context of WUR applications, sleep mode serves as an essential functionality that facilitates energy conservation and extends the lifespan of device batteries. Current research is primarily dedicated to the advancement of novel sleep mode techniques with the aim of significantly augmenting the energy efficiency of Wireless Underground Receiver (WUR) systems. Table 3 shows the studies that implemented sleep strategy in WUR.

Table 3
The studies implemented sleep strategy in WUR

No	Author	Source	Article title	Method	Result
1	Lopez-Aguilera *et al.,* [15]	IEEE Wireless Communications Letters	Design and Implementation of a Wake-Up Radio Receiver for Fast 250 kb/s Bit Rate	Putting together a wake-up receiver (WuRx) using off-the-shelf parts and a microprocessor unit to decode at the fastest bit rate of 250 kb/s that TGba allows.	A WuRx module has been developed for OOK-based WuC decoding using the fastest bit rate of 250 kb/s allowed by TGba. The module is feasible and performs well in various cases, demonstrating its robustness and convenience in implementing the Hold Sensing state.
2	Kim *et al.,* [16]	IEEE Journal Of Solid-State Circuits	A-123-dBm Sensitivity Split-Channel BFSK Reconfigurable Data/Wake-Up Receiver for Low-Power Wide-Area Networks	A 900-MHz high-sensitivity split-channel binary frequency-shift keying (SC-BFSK) reconfigurable data/wake-up receiver (RX) for low-power wide-area networks (LPWANs).	The suggested RX chip, which is made in 55-nm CMOS technology, is 106 dBm sensitive to the unencoded signal and loses 0.88 mW. It has a sensitivity of -123 dBm, a data rate of 0.39 kbps, and a wake-up lag of 81.92 ms when it combines the data and wake-up modes.
3	Niculescu *et al.,* [17]	IEEE Internet Of Things Journal	Energy-Efficient, Precise UWB-Based 3-D Localization of Sensor Nodes With a Nano-UAV	Ultrawideband (UWB) and wake-up radio (WUR) technologies: use UWB to communicate and send data between the nano-UAV and the nodes; WUR keeps the sensors' power use as low as possible.	A new error-correction model makes localization even more accurate by an extra 25%. The WUR makes the whole process of localization and data sharing only 24 mJ at the sensor node. This is 50 times more energy efficient than the current best method for achieving the same level of localization accuracy.

3.2 Small-Cell Networks

Small-cell networks play a crucial role in the overall 5G ecosystem, with energy efficiency being a critical consideration in their design and operational processes. One potential strategy for enhancing energy efficiency involves the implementation of sleep mode techniques, which enable tiny cells to transition into a state of reduced power consumption while they are not actively being utilized. Various sleep mode algorithms can be implemented in small-cell networks, encompassing small cell-driven, core network-driven, and user equipment-driven approaches. In the sleep mode of small cell operation, the decision to enter sleep mode is autonomously made by the small cell, taking into consideration its own traffic load and various other criteria. The core network-driven sleep mode entails the core network making decisions on the activation of sleep mode for small cells, which is determined by analyzing network-wide traffic patterns and considering several other criteria. According to Ashraf *et al.,* [18], the user equipment enters sleep mode autonomously by considering its usage patterns and various other parameters.

Current scholarly investigations have been mostly directed towards the advancement of energy-efficient sleep tactics specifically tailored for small-cell networks. An UBS-assisted sleep method with low complexity has been developed for small-cell networks, and its effectiveness has been validated by simulation Chang *et al.,* [19]. Sun and Chang [20] introduced a study that presented a strategy for user association and cell sleeping in multi-tier ultra-dense small cell networks, with the aim of optimizing energy efficiency. Furthermore, there have been proposed solutions in the literature that aim to enhance energy efficiency by transferring the traffic burden of a small cell to other small cells, known as traffic-aware sleeping strategies [21].

In general, the use of sleep mode approaches presents a potentially advantageous approach to boost the energy efficiency of small-cell networks. Current scholarly investigations are mostly dedicated to the exploration and development of novel strategies aimed at augmenting the efficacy of these techniques. Table 4 shows the studies that implemented sleep strategy in small-cell networks.

Table 4
The studies implemented sleep strategy in small-cell networks

No	Author	Source	Article Title	Method	Result
1	Liu *et al.,* [22]	Wireless Personal Communications	Robust Power Control for 5G Small Cell Networks with Sleep Strategy	The resource scheduling and power control strategy is studied for a two-tier 5G network system, which is comprised of a central macrocell and several small cells.	Numerical results are given to illustrate the effectiveness of the joint resource scheduling scheme.
2	Chang *et al.,* [23]	IEEE Communications Letters	Energy-Efficient Sleep Strategy With Variant Sleep Depths for Open-Access Femtocell Networks	Enhance the energy-efficiency (EE) for hyper-dense small-cell networks by designing a low-complexity sleep strategy for base-stations (BSs)	Compared with the conventional schemes, a remarkable 72% and 51% enhancement of EE can be achieved and more BSs can operate in the lower-energy modes.
3	J. Wu *et al.,* [24]	Digital Communications and Networks	SMDP-based sleep policy for base stations in	The energy efficiency optimization of the Macro-Femto	The proposed SMDP-based adaptive sleep strategy of the FBS

			heterogeneous cellular networks	heterogeneous cellular network, dynamic sleep algorithm of the FBS based on the value iteration	can effectively reduce the network energy consumption.
4	Sun *et al.,* [25]	Applied Intelligence	Energy efficiency-driven mobile base station deployment strategy for shopping malls using modified improved differential evolution algorithm	A green mall traffic model based on mobile base stations with a dynamic sleep strategy is proposed for surges of shopping mall traffic	Compared with the traditional differential evolution (DE) algorithm and the DE series algorithms recently published in Swarm and Evolutionary Computation, a journal with high impact factors, MIDE can effectively optimize the system model and improve its energy efficiency, saving 1.1%-56.4% in simulation experiments.
5	Li *et al.,*[26]	IEEE Access	Energy-Efficient Deployment and Adaptive Sleeping in Heterogeneous Cellular Networks	A joint sleep strategy of MBSs and that of SBSs	Deduced joint optimal densities of the SBS and the MBS are accurate, and energy efficiency is improved when SBSs and MBSs adaptively sleep.
6	Ma *et al.,* [27]	Energy Reports	Energy consumption optimization of 5G base stations considering variable threshold sleep mechanism	An energy consumption optimization strategy of 5G BSs considering variable threshold sleep mechanism (ECOS-BS)	Compared to current strategies, the ECOS-BS strategy can dynamically adjust BSs' optimal sleep threshold on the premise of considering UEs' dynamic changes
7	Natarajan and Rebekka [28]	Physical Communication	Stochastic geometry analysis of coverage probability in energy efficient dense heterogeneous network with sleep control mechanism	A strategic small cell sleeping technique. A heuristic method based on distance and load awareness strategy in which the small cells with fewer users near the macrocell will be put into sleep mode.	Simulation analysis on the stochastic geometry model indicates that the proposed sleep strategy significantly improves the network EE than the prevailing sleep control strategies while assuring seamless, efficient coverage in the sleep cell areas.

3.3 Wireless Sensor Networks (WSN)

The significance of sleep scheduling in wireless sensor networks (WSNs) is crucial for ensuring optimal energy efficiency and extending the overall lifespan of the network. Sleep scheduling is a commonly employed strategy in wireless sensor networks (WSNs) with the objective of conserving energy by minimizing the energy consumption of the individual nodes. The implementation of sleep scheduling can effectively minimize the occurrence of the idle listening state, which is known to result in energy inefficiency. This optimization strategy consequently leads to a reduction in energy consumption and an extension of the network's overall lifespan [29]. The significance of sleep scheduling in Wireless Sensor Networks (WSNs) is emphasized by its capacity to manage the trade-offs among energy usage, network responsiveness, and transmission delays. The implementation of sleep scheduling has been shown to enhance the longevity of the network. However, it is important to note that there is a possibility of introducing transmission delays, particularly when the network size expands. Hence, it is imperative to prioritize the development of delay-aware sleep scheduling techniques in order to address broadcasting delays and guarantee minimal broadcasting delay from all nodes within the Wireless Sensor Network (WSN) [30].

Moreover, sleep scheduling algorithms in Wireless Sensor Networks (WSNs) can be categorized into three main types: synchronous schemes, semi-synchronous schemes, and asynchronous schemes. Each of these schemes possesses distinct advantages and disadvantages. The procedures implemented in wireless sensor networks have been specifically designed with the objective of reducing energy consumption and extending the overall lifespan of these networks [31].

In conclusion, the establishment of sleep scheduling holds significant significance within the context of Wireless Sensor Network (WSN) applications due to its direct influence on energy efficiency, network longevity, and transmission latency. The optimization of performance and endurance in wireless sensor networks necessitates the development and implementation of efficient sleep scheduling algorithms. Table 5 shows the studies that implemented sleep strategy in WSN.

Table 5
The studies implemented sleep strategy in WSN

No	Author	Source	Article Title	Method	Result
1	Niculescu *et al.,* [32]	Sustainable Computing-Informatics & Systems	Fly, Wake-up, Find: UAV-based Energy-efficient Localization for Distributed Sensor Nodes	An energy-efficient and accurate localization algorithm - based on multi-lateration - that is computationally inexpensive and robust to in-field noise.	Due to the presence of the WUR and the proposed lightweight algorithm, the entire localization-acquisition cycle requires only 31 mJ on the sensor node.
2	Patil *et al.,* [33]	Wireless Personal Communications	A Novel AEB-AODV Based AADITHYA Cross Layer Design Hibernation Algorithm for Energy Optimization in WSN	To address some of key WSN challenges, a novel routing protocol, a hibernation algorithm (cross layer design) along with the low power hardware design for achieving energy efficiency	Simulation results of AEB-AODV routing protocol and actual test readings of the developed hardware have shown that this method is effective in optimizing the energy usage in the nodes and hence improves the life

					expectancy of the WSN used for any general application.
3	Khokhar *et al.,* [34]	CMC-Computers Materials & Continua	Diffusion Based Channel Gains Estimation in WSN Using Fractional Order Strategies	Fractional order modified diffusion LMS algorithms are applied in the two configurations of combine-then-adapt and adapt-then-combine	Experimental results are shown for different number of nodes and fractional orders. The simulation results establish that the accuracy of the proposed scheme is far better than its classical counterparts, therefore, helps better solves the channel gains estimation problem in a distributed wireless environment.
4	Abdal-Kadhim and Leong [35]	International Journal Of Electronics Letters.	Electrical power flow of typical wireless sensor node based on energy harvesting approach	A comprehensive mathematical model for a wireless sensor node power flow and consumption powered by energy harvesting. A simple periodic (wake-up; take readings; transmit; sleep) algorithm is developed for the sake of wireless sensor nodes' power flow calculation.	The microcontroller MCU consumed the highest power of 0.66 mW in the proposed node, followed by the wireless transmitter 0.33 mW, and the sensor module 0.18 mW at the active mode. However, the sensor module consumed very high power, with a value of 0.18 mW compared to the other modules in the proposed sensor node during the sleep mode.
5	Kombo *et al.,* [36]	IEEE Access	Design and Application of a Low-Cost, Low- Power, LoRa-GSM, IoT Enabled System for Monitoring of Groundwater Resources with Energy Harvesting Integration	A low-cost, low-power, wireless sensor network for groundwater monitoring (LWNGM) was developed to provide near real-time groundwater level data to support prudent decision making in groundwater resource management	Practical evaluation determined that, the system is reliable and transferable, particularly in areas with a limited budget for hydrologic management
6	Fu *et al.,* [37]	Applied Sciences-Basel	LEACH-MTC: A Network Energy Optimization Algorithm Constraint	An improved algorithm LEACH-MTC (LEACH with Moving Target Constraint) based on low energy adaptive clustering	Simulation results show that the proposed LEACH-MTC algorithm can not only ensure the

		as Moving Target Prediction	hierarchy protocol (LEACH).	real-time consistency between the changing direction of area and the direction of target movement, but also increase the number of working nodes' survival and reduce the network energy consumption.

3.4 Microcontroller Applications

The implementation of sleep techniques in microcontrollers plays a critical role in the reduction of power consumption in embedded systems (see Table 6). The aforementioned solutions encompass the utilization of low-power modes for the microcontroller during periods of inactivity, enabling energy conservation while maintaining the ability to promptly restart regular functions when necessary. A range of methodologies are utilized to maximize the efficiency of sleep modes, including the implementation of extensive clock gating to deactivate superfluous circuits, as well as the application of meticulous analysis to assess the interplay between response time and power conservation [38].

Furthermore, microcontrollers such as the Cortex®-M CPUs offer support for various sleep modes, including Sleep and Deep Sleep [39]. The many modes available to the microcontroller allow for customization of power consumption based on the individual needs of the application, hence promoting optimal energy utilization. In order to achieve energy-efficient operation in microcontroller-based systems, it is crucial to possess a comprehensive comprehension of appropriate sleep methods and to successfully implement them [40].

Table 6
The studies implemented sleep strategy in microcontroller applications

No	Author	Source	Article title	Method	Result
1	Ripoll-Vercellone *et al.,* [41]	IEEE Transactions on Instrumentation and Measurement	LED-Based Wake-Up Circuit for Microcontrollers	A wake-up circuit for a microcontroller (MCU) that uses a light-emitting diode (LED), operating as a photodetector, illuminated by a smartphone flashlight. The wake-up circuit consists of a high-pass filter and a voltage-level translator that interfaces the LED, with a suitable resistor in parallel, to the MCU.	Proposes, analyzes, and tests a wake-up circuit for a microcontroller (MCU) that uses a light-emitting diode (LED), operating as a photodetector, illuminated by a smartphone flashlight.
2	Sifuentes *et al.,* [42]	Sensors	Seat Occupancy Detection Based on a Low-Power Microcontroller and a Single FSR	A microcontroller-based measurement system to detect and confirm the presence of a subject in a chair.	The MCU-based circuit with a smart wake-up shows a standby current consumption of 800 nA, and requires an energy of

					125 mu J to carry out the measurement after the wake-up.
3	Tang *et al.,* [43]	Measurement	A miniature and intelligent Low-Power in situ wireless monitoring system for automotive wheel alignment	An energy-efficient onboard wheel alignment wireless monitoring system (WAWMS) is developed to detect wheel misalignment in real time. To minimise power consumption, a dual wake-up strategy is proposed to wake the microcontroller by a real-time clock (RTC) and an accelerometer.	To minimise power consumption, a dual wake-up strategy is proposed to wake the microcontroller by a real-time clock (RTC) and an accelerometer.
4	Choi *et al.,* [44]	Nano Energy	Stretchable triboelectric multimodal tactile interface simultaneously recognizing various dynamic body motions	Mimic such characteristics of the human tactile receptors. stretchable triboelectric nanogenerator (TENG) is designed for the stimuli-responsive potential generator.	This study demonstrates a wearable low-power remote tactile interface that controls the 3D movements of a mobile device (drone) by the body motions.
5	Carretero *et al.,* [45]	Applied Sciences (Switzerland)	Autonomous active tag using energy harvesting strategies	The power sources of these active tags employ energy harvesting techniques, specifically, solar and mechanical techniques.	This autonomous active tag is a demonstration that the integration of energy harvesting techniques, supercapacitor storage and the management of low power modes for transceivers, microcontrollers, and memories creates a device without energy dependencies
6	Abdulkareem *et al.,* [46]	ARPN Journal of Engineering and Applied Sciences	A novel and fully synchronized laser-based wireless communication system	A novel approach in designing and implementing a laser-based wireless channel communication system.	The proposed work proved the simplicity in design as well as the low cost value PIC16F887 microcontroller. Moreover, the results of data transferring show an exceptional accuracy with an errorfree system.

3.5 Other Applications

Table 7 shows the studies that other than the above topics: wake up radio, small-cell networks, Wireless Sensor Network (WSN) and microcontroller.

Table 7
The studies implemented sleep strategy in other applications

No	Author	Source	Article Title	Method	Result
1	Xu and Chen [47]	IEEE Communications Letters	Information Freshness in Sleep-Wake Server Systems	Show both analytically and numerically that reducing the sleeping probability or the length of the sleeping period for these three strategies will reduce PAoI, and increasing the setup time variability for N-policy and multiple sleep strategy will also reduce PAoI.	An information updating system in which the server falls asleep after a random idling period if no arrival occurs.
2	Yao *et al.,* [48]	IEEE Sensors Journal	Coverage Control Algorithm for DSNs Based on Improved Gravitational Search	Aiming at enhancing the DSNs coverage performance, a coverage control algorithm based on improved gravitational search (IGSCCA)	The simulation results showed that this paper has great advantages in coverage rate, energy utilization rate and redundancy rate.
3	Duan [49]	Journal Of Sensors	Application of Motion Sensor Fusion in Special Competitive Sports	A motion acquisition system which is divided into two parts: a signal acquisition unit and a data processing unit. With ARM7 and three-axis accelerometer ADXL330 as the core, it can realize information acquisition and data analysis of up to 5 sensor network nodes.	The experimental results verified the use of the sports information acquisition system to collect and analyze sports information.
4	Hirsch [50]	Frontiers in Computer Science	Speech Assistant System With Local Client and Server Devices to Guarantee Data Privacy	A keyword recognition algorithm that can be implemented in the client despite its limited computing resources. The control of the whole dialogue has been integrated in our client, so that no further server is needed	In the listening mode, the energy consumption of the microphone is so low that a client system can be active for months with an energy supply from standard batteries only.

4. Conclusions

From the result, there are five categories of sleep strategy applications using microcontroller which are (1) wake up radio, (2) small-cell networks, (3) Wireless Sensor Network (WSN), (4) microcontroller and (5) other applications. All the studies show the improvement in power consumption of the system after implementing the sleep strategy. For example: By utilizing the sleep strategy in Wireless Underground Radio (WUR), the complete cycle of localization and data exchange consumes a mere 24 millijoules (mJ) at the sensor node. This energy expenditure is significantly more efficient, approximately 50 times, compared to the current leading technology while maintaining a

similar level of precision in localization. Furthermore, from this review, sleep strategy can be seen most applied to either microcontroller itself or to the big system to optimize the power consumption. There is no research applying sleep strategy to minimize the power on both microcontroller and the system itself. Therefore, this comprehensive systematic review has excavated the opportunity to enhance the implementation of sleep strategy on both microcontroller and the system itself. When microcontroller itself applies sleep strategy and the system, this step will improve power optimization in microcontroller applications, especially in the Internet of Things (IoT) which is crucial in power management.

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