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# A Survey on Different Wake-up Scheduling in WSN

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## Abstract

***A wireless sensor network defined the efficient wakeup scheduling schemes for energy constrained sensor nodes that adhere to the bidirectional end-to-end delay constraints posed by such applications and actuating applications require immediate notification of rare but urgent events and also fast delivery of time sensitive actuation commands. We want to focus on wakeup scheduling in WSN schemes and obtained their study in Asynchronous Wakeup Scheduling, Heterogeneous Wake-up Scheduling, TDMA- Protocol-Scheduling, and Quorum-Based Wakeup Scheduling. All the wakeup scheduling patterns such as synchronized (SMAC) and staggered patterns (DMAC) are considered and we also introduced new efficient wakeup patterns such as crossed-ladders pattern which outperforms other methods. We can show that our proposed techniques significantly improve the performance and allow for much longer network lifetime while satisfying the latency constraints.***

## Keywords

***Wireless Sensor Network, Wakeup Scheduling, Energy-efficient Scheduling, Asynchronous Wakeup Scheduling, Heterogeneous Wake-up Scheduling, TDMA-Protocol-Scheduling and Quorum-Based Wakeup Scheduling, Synchronized (SMAC) and staggered patterns (DMAC).***

## 1. Introduction

A wireless sensor network is a collection of nodes organized into a cooperative network. A Wireless Sensor Network (wsn) consists of node which senses the data and performs computing of data for specific application. WSN nodes are save energy to increase the lifetime of sensor node. Most of the WSN devices powered with small batteries are deployed in the remote area, and it is not easy to recharge or replace battery once they are deployed at those remote areas. So, design node in such way so that it save energy and increase the lifetime of sensor node with sensor node. The energy consumption of wireless exchange of data between sensor devices dominates other sensor functions such as sensing and computing. [2]. A wireless sensor network consists of multiple detection stations called wireless sensor nodes, each of which is small, lightweight and portable. The power for each sensor node is derived from the electric utility or from a battery [1].

### 1.1 Scheduling

The process scheduling is the activity of the process manager that handles the removal of the running process from the CPU and the selection of another process on the basis of a particular strategy. Process scheduling is an essential part of a Multiprogramming operating system. Such operating systems allow more than one process to be loaded into the executable memory at a time and loaded process shares the CPU using time multiplexing. Scheduling queues refers to queues of processes or devices. When the process enters into the system, then this process is put into a job queue. This queue consists of all processes in the system. The operating system also maintains other queues such as device queue. Device queue is a queue for which multiple processes are waiting for a particular I/O device. Each device has its own device queue[6].

### 1.2 WSN Scheduling

A Wireless sensor network scheduler, also called packet scheduler, is an arbiter program that manages the sequence of wireless sensor network packets in transmit and receive queues of the wireless network interface controller, which is use circular data buffer. There are several wireless sensor network schedulers available for the different operating system. Wireless sensor networks are composed of a large number of sensor nodes, which communicate in a radio channel. The main aim of the sensor network consists of a sensing a certain physical parameter, collecting data and forwarding them to the base station where the information is computed.[4] The topology of WSN is mostly considered as a mesh type and the communication can be either single-hop or multi-hop depending typically on the size of the network. Even combination of both can be used. WSN networks are in a certain way similar to MANET networks. There are, however, two gaps between them: energy

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awareness and events driven by sensed physical variable. WSN networks are crucially energy constrained because the nodes are powered from non-rechargeable batteries in most cases. On the contrary, the devices of MANET network are typically powered from batteries, which can be easily recharged or replaced. Moreover MANET devices are not as small as WSN devices, thus, the capacity of batteries can be higher. That means both technologies are energy aware since they are run from batteries but in WSN energy consumption is more critical issue and all network processes have to be designed with minimal energy demands.[5][7].

## 2. Classification for WSN Wakeup Scheduling

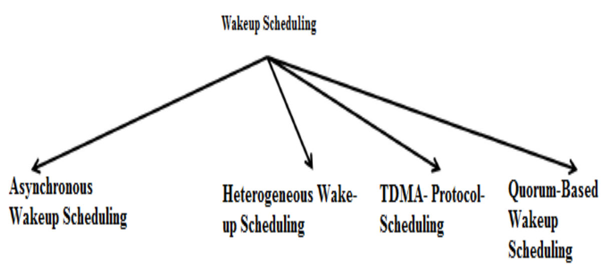


**Figure 1: Classification of Wakeup Scheduling**

### 2.1 Asynchronous Wakeup Scheduling

Asynchronous wakeup does not require clock synchronization. In this approach, each node follows its own wakeup schedule in idle state, as long as the wakeup intervals among neighbors overlap. To meet this requirement, nodes usually have to wakeup more frequently than in the scheduled rendezvous mechanism. However, there are many advantages asynchronous wakeup, such as easiness in implementation and low message overhead for communication. Furthermore, it can ensure network connectivity even in highly dynamic networks [3].

### 2.2 Heterogeneous Wake-up Scheduling

The heterogeneous wake-up scheduling means that nodes execute different wakeup independent schedules to reflect their remaining/residual energy [13]. There are different types of heterogeneous wake-up scheduling: quorum duty-cycling schedule and low duty cycling schedule.

### 2.3 TDMA- Protocol-Scheduling

The TDMA protocol must be energy efficient by reducing the potential energy wastes and send the senses data to the sink without further delay. TDMA protocols reduce the retransmission because collision does not happen in TDMA protocol. The types of communication patterns that are observed in sensor network applications should be investigated, since these patterns determine the behavior of the sensor network traffic that has to be handled by TDMA protocol. This TDMA protocol uses energy efficient Wakeup scheduling (EEWS) algorithm for sensor nodes which reduces the number of wake-up**.** Wake-up means, when any node receives or transmits data then it comes in wakeup mode. In this protocol, to reduce the energy cost by scheduling the wireless sensor node in particular area. once for receiving data from its all child nodes and once for transmission the data to its parent node. To design a TDMA protocol for wireless sensor network the following parameter must be considered. Firstly, TDMA protocol should be energy saving protocol. Secondly, another parameter of wireless sensor network is routing and adaptability to change. If any change in network size, node density, and topology, should be handled effectively by protocols. Fast and efficient query response is another essential attribute for network performance in wireless sensor networks. Co-channel interference is also a problem; hence interference should be minimized where ever possible. There are other attributes such as latency, throughput, and bandwidth utilization which may be considered secondary for application of sensor networks [8].

TDMA has a natural advantage of collision-free medium access but in some protocols this leads to interference due to slot reuse. Time synchronization is required in these protocols because of clock drift problem. Adaptation to topology changes is another difficulty faced by TDMA system as these changes are caused by insertion of new nodes, exhaustion of battery capacities, broken links due to interference, the sleep schedules of relay nodes, and scheduling caused by clustering algorithms. The slot However, it is not easy to change the slot assignment within a decentralized environment for traditional TDMA, since all nodes must agree on the slot assignments.

### 2.4 Quorum-Based Wakeup Scheduling:

In quorum based wakeup scheduling can be used quorum-based power saving (QPS) protocol, has recently been proposed as a solution for asynchronous wakeup scheduling. In a QPS protocol, the time axis is divided into beacon intervals. Given an integer n, a system defines a cycle, which specifies the wake/sleep scheduling pattern during n continuous intervals for each node. We repeat n the cycle length, because the pattern repeats n intervals. A node may stay awake or sleep during each beacon interval. QPS protocols can guarantee that at least one awake interval overlaps between two adjacent nodes, with each node being awake for only beacon intervals [12].

Most previous works only consider homogenous quorum systems for asynchronous wakeup scheduling which means that quorum systems for all nodes have the same cycle length and same pattern.

However, many WSNs are increasingly heterogeneous in nature i.e., the network nodes are grouped into clusters, with each cluster having a high-power cluster head node and low-power cluster member nodes. Thus, it is desirable that heterogeneous sensor nodes have heterogeneous quorum-based wakeup schedules [3].

**Table 1: Taxonomies**

| Paper | Content | Method / Tools | Achievement |
|---|---|---|---|
| Asynchronous Wakeup Scheduling | Own wakeup schedule in idle state. Intervals among neighbours overlap. | Scheduled rendezvous mechanism. | Asynchronous wakeup does not require clock synchronization .Implementation and low message overhead for communication. |
| Heterogeneous Wake-up Scheduling: | Wakeup independent schedules. | Quorum duty-cycling schedule and low duty cycling schedule method. | Each node performs independent wakeup date flow. |
| TDMA- Protocol-Scheduling | Energy efficient by reducing the potential energy wastes. How to node receives or transmits data using TDMA. | This TDMA protocol uses energy efficient Wakeup scheduling (EEWS) algorithm. | TDMA protocols reduce the data retransmission. |
| Quorum-Based Wakeup Scheduling | Quorum based wakeup scheduling. | Quorum-based power saving (QPS) protocol method. | A high-power cluster head node and low-power cluster nodes member. |

## 3. Wakeup scheduling in WSN

A popular approach towards increasing longevity of sensor networks is by employing wakeup scheduling where each nodes stay in low-power or sleep modes for most of the time, periodically wakeup to check for activity. This increased longevity, however, comes at the cost of increased data delivery latency since a forward node has to wait until its next-hop neighbour awakens and is ready to receive the data. Researchers in wireless and sensor networks continue to search for new wakeup techniques to save power [9]. Scheduling methods can be classified into two main type:

### 3.1 Scheduled wakeups

The nodes follow possibly random wakeup patterns. Time synchronization proved the nodes in the network is generally assumed. However, in this process asynchronous wakeup mechanisms which don’t require synchronization among the different nodes are also categorized in this class. Although asynchronous methods are simpler to implement, they are not use an efficient as synchronous schemes, and in the worst case their guaranteed delay can be very long.

### 3.2 Wakeup on-demand (out-of-band wakeup)

The nodes can be signalled and awakened at any point of time and then a message is sent to the node. This is can be implemented by employing two wireless interfaces. The first radio is used for communication and by the second ultra-low-power radio which is used only for paging and signalling. Stem and its variation, and passive radio-triggered solutions are examples of this class of wakeup methods[16]. Although these methods can be optimal in terms of both delay and energy, they are not yet practical. The cost issues, currently limited available hardware options which results in limited range and poor reliability, and stringent system requirements prohibit the widespread use and design of such wakeup techniques. Consequently, there is a need for efficient scheduled wakeup schemes which are reliable and cost-effective and can also guarantee the delay and lifetime constraints.We are defining on the synchronous scheduled wakeup methods which provide bidirectional delay guarantees. We analyse methods and introduce new efficient wakeup methods that outperform the existing ones. We present a novel class of wakeup methods called multi-parent schemes which assign multiple parents (forward nodes) with different wakeup schedules to each node in the network. This method takes a cross-layer approach and exploits the existence of multiple paths between the nodes in the network to significantly improve the energy-efficiency of wakeup process and therefore increase the life-time of the network while meeting the message delay constraints.

We derive the best-case, worst-case, and generally the distribution of delay for many existing and our new wakeup schemes process, and also characterize the trade-offs between power consumption and guaranteed delay for many different wakeup mechanisms [5].

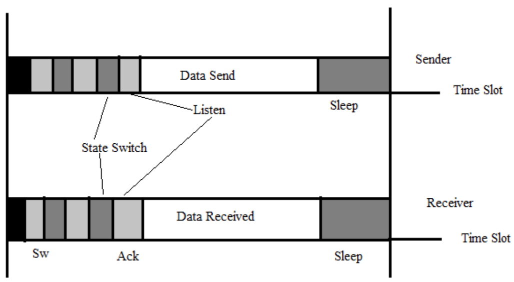


**Figure 2: Synchronous data send and receive in wakeup scheduling**

### 3.3. Channel Sniffing

Nodes in the network wake up from time to time and select the channel for activity. This is performed by observing to the channel for a short period of time and measuring the signal strength. If the signal strength exceeds a pre-determined threshold, the node remains a wake, otherwise it powers itself down. This entire process is called sniffing the channel [5].

### 3.4. Time Synchronization

We consider that a network time synchronization protocol maintains a notion of time between various sensor nodes in the network. Time synchronization in wireless sensor networks is well researched and several implementations can achieve synchronization within few of μsec. As such, synchronizing nodes within an accuracy of few msec, which is required by the wakeup schedules, is a relatively easy task. Although the time synchronization protocol may create additional energy burden for the system, in most delay sensitive applications this extra energy cost is either negligible in comparison with the energy consumed by the wakeup process2 and/or will be compensated by the energy saving that can be achieved by employing an efficient synchronous wakeup method. Therefore, for delay-sensitive applications, synchronous wakeup methods are preferred due to their overall energy-efficiency. [10]

### 3.5 Network Topology

Each node in the network is presented by a node in a graph and a link between two nodes represents ability to communicate with each other. An initial connectivity graph is formed by the base station during network initialization followed by occasional updates to account for temporal changes in the wireless channel. While wireless link qualities are subject to changes temporally, two static nodes that are connected via a reliable link rarely experience a complete change in their connectivity over short periods of time.[15] In this work we consider that the sensor network deployment is such that every node has few neighbours with highly reliable links. In such a network, if only reliable links are used for communication, the connectivity graph itself is not subject to frequent changes. As such, we assume that the connectivity graph formed by using the reliable links of the network is stationary [5].

### 3.6 Variables and Notation

There are N nodes in the network. Levels are assigned to various nodes in the network in a breadth-first order based on the connectivity graph. The base station is assigned a level 0. Essentially, level of a node signifies the minimum number of hops from the node to the base-station [11].

## 4. Wakeup Scheduling Technique

### 4.1 MAC Protocol

A wakeup scheduling techniques can be found in a MAC protocol for sensor wireless networks called S-MAC, was introduced where the idea of duty-cycling and scheduled sleeping of the nodes is incorporated in the MAC layer. Each node follows a particular period for active sleep cycle, and the nodes that are close to one another synchronize their active cycles together[17]. T-MAC is an extension of the previous protocol which adaptively adjusts the sleep and wake periods based on estimated traffic flow to increase the power savings and reduce delay. DMAC is an efficient data gathering protocol for sensor networks where the communication pattern is restricted to a unidirectional tree. It is uses staggered wakeup schedules to create a pipeline for data propagation to reduce the latency of data collection process significantly. A similar wakeup scheme provides good delay in one direction but it is not efficient when bidirectional delay guarantees are required. In a protocol is proposed for scheduling the wakeup time of different nodes such that detection delay is minimized i.e., each node point in the environment is sensed within some finite interval of time. The algorithm shows mainly useful whether many redundant sensor nodes in the network such that the same point is covered by multiple sensors. They consider low traffic network with arbitrary communication flows and show that minimizing the end-to-end communication delay is in general NP-hard. However, they present efficient heuristic methods to find the best schedules and prove the optimality of different wakeup patterns under specific conditions for special tree and ring topologies [18].

In model it is defined to minimize the worst-case end-to-end overall delay which includes both transmission delay and detection delay. Unlike the model in where general traffic flows are assumed, we have consider a specific yet very common and practical traffic pattern where the base station (a central node) is either the source or destination of the data (forward direction) or it is the sink or the final receiver of the data (backward direction) (see Figure. 2).

By focus on this traffic pattern we are able to design very energy-efficient methods and guarantee a significantly better delay performance even for data collection or monitoring applications where the backward delay.

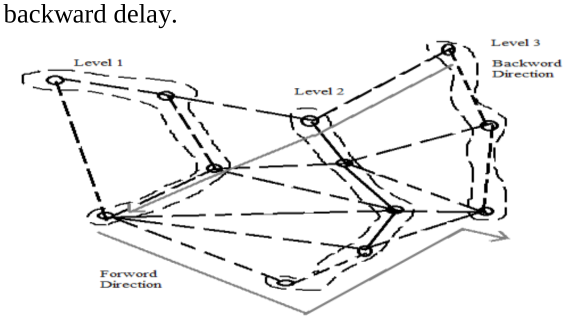


**Figure 3: Network and Traffic Model**

1) Forward Direction (Downlink): The base station sends a data to one of nodes in the network.
2) Backward Direction (Uplink): A regular node sends a data to the base station.

Several wireless sensor network nodes today, are often equipped with passive event detection capabilities that allow a node to detect an event while it is in sleep mode. In this process provide ultra-low-power, low-rate periodic sampling mechanisms for rare event detection. Upon the detection of an event, the sensor node is immediately wake up (within several µsec) and is ready to transmit a notification message to the base-station. Similarly, it is use to base-station is often required to transmit imperative commands or queries to sensor nodes that may originate asynchronously. The Messages in either direction, thus, originate at random times (asynchronously)and this implies that data may potentially originate at an inopportune time when all other nodes in the network are in sleep mode and not ready to receive the message. While these messages occur infrequently, they react urgency; as such their delivery demands non-negotiable worst case delay bounds. For the rest of the discussion delay is defined as the time duration between generations of a message at a node (base-station or a regular node) until its eventual delivery at the destination node[14]. Node wakeup at most twice: once a process for receiving data from its all child nodes and once for transmission the data to its parent node. In homogeneous network, Let's denote the set of children nodes of node in data gathering tree. Then we say that constitutes a virtual cluster. The weight is define the total number of time slots that node should wakeup to receive the data from its children in the data gathering tree

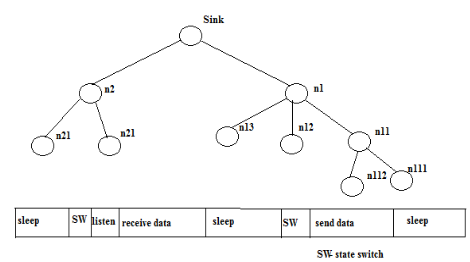


**Figure 4: Wakeup scheduling through send and receive data**

**Advantage:**
In this protocol can use the energy conserving. Energy saved by reducing the state transition from wakeup to wakeup state and from wakeup.

We can use the dramatically reduces the cost of the clock synchronization. This scheduling protocol process also reduces time delay because slots are reused.

Disadvantage: The main disadvantage defined in protocol. The clusters which have contention with each other and allot different time slot to them. Due to use time slot reuse co-channel interference can be occur if two contended clusters use same time slot.[2]

## 5. Summary of method uses

| Paper name | Constraint | Analytical Tools/Method | Achievement |
|---|---|---|---|
| 1. Efficient wakeup scheduling schemes for energy constrained sensor nodes. | Wireless Sensor Network (WSNs).<br>Wakeup Scheduling. | Wakeup methods.<br>Multi-parent schemes.<br>Energy-efficient Algorithms. | Improve the energy efficient schemes performance. |
| 2.Energy-efficient Wakeup Scheduling for Maximizing Lifetime of Networks | Perform energy-intensive tasks such as data-aggregation and data-forwarding | Network-connectivity or execute a set of tasks in a distributed fashion. | End-to-end delay constraint is met |
| 3. Energy-Efficient Local Wake-up Scheduling in Wireless Sensor Networks | Active sensor runs out of energy,<br>colony optimization based method. | TDMA and MAC layer protocol.<br>Local wake-up scheduling (LWS) strategy | Improve the low data-rate WSN.<br>Simulation results reveal that mc-ACO yields better performance |
| 4. Interference-Free Wakeup Scheduling with Consecutive Constraints in Wireless Sensor Networks | All communication graphs.<br>grid topologies | Traditional wakeup scheduling, compact wakeup scheduling | The optimum number of time slots in a period for trees and grid graphs |
| 5.<br>Scheduler for multichannel flow-level dynamics | Full CSI Markov chain Single cell (OFDM) | Throughput-optimal wireless systems with Not fully backlogged Lagrangian multipliers | Multi-carrier<br>Stability |
| 6.Optimal scheduler for HSDPA networks . | Full CSI.<br>Not fully backlogged Error free transmission<br>Traffic :Bernoulli | Finite state markov chain<br>Dynamic programing markov process.<br>Single cell (HSDPA)<br>Downlink | Decision process Fairness.<br>Error free transmission Markov. |
| 7.A Survey on Scheduling Algorithms for Wireless Sensor Networks | Wireless sensor networks (WSN).<br>Traffic analysis<br>Environmental monitoring Industrial<br>Process monitoring<br>Tactical systems. | Large-scale wireless sensor networks.<br>Time<br>Division Multiple Access Protocol.<br>MAC layer | Sensor networks.<br>Sensor network properties |
| 8.Timing is everything: the impact of wakeup<br>Schedule<br>Distribution on asynchronous power save<br>Protocols | Asynchronous power save protocols | (CBR) flows.<br>CSMA/CA-based ad hoc networks | Nodes independently |
| 9.Heterogenous Quorum-based Wakeup<br>Scheduling in Wireless Sensor Networks | Cyclic quorum system pair (cqs-pair )<br>grid quorum system pair (gqs-pair ). | HQB wakeup scheduler<br>Homogenous quorum systems | Measurements further validate<br>The analytically-established performance |
| 10. Lifetime Maximization in Wireless Sensor Networks Using Residual Energy Sleep Scheduling | Random deployment of sensors<br><br>Sleep periods | Residual energy sleep scheduling (RESS)<br><br>Node self-scheduling scheme | Avoid redundancy.<br><br>Minimize energy consumption |
| 11.Energy-Efficient Wake-Up Scheduling<br>for Data Collection and Aggregation | Systematic gather.<br>Key challeneg. | MAC layer protocol<br>low-data-rate WSNs | Consume energy for state transition<br>Energy consumption |
| 12.Througput-optimal scheduler that account for | Non-full CSI<br>Not fully backlogged | Markov chain<br>Lagrangian multipliers | Single cell downlink<br>Throughput-Optimal |

| | | | |
|---|---|---|---|
| flow level dynamics | Traffic flow level with two class of flows | Lyapunov drift | Stability. |
| 13.Opportunistic Scheduler for cognitive radio network. | Non-full CSI<br>Not fully backlogged<br>Traffic :Bernoulli | Markov chain<br>Lyapunov drift<br>Lyapunov optimization<br>Maximum weight match | Muti-cell<br>Throughput optimal |
| 14. Schedular for multichannel wireless systems with flow-level dynamics. | Fully CSI<br>Not fully backlogged<br>Traffic : Generic | Markov chain<br>Lagrangian multipliers<br>Lyapunov drift<br>Single cell (OFDM) | Throughput- optimal stability |
| 15.Optimal schedular for cooperative cognitive radio network | Fully CSI<br>Fully backlogged | Lyapunov drift<br>Lyapunov optimization | Single cell<br>Stability |
| 16. Scheduler for multicarrier wireless system. | Fully CSI<br>Not fully backlogged<br>Traffic: Generic | Greedy algorithms<br>Dynamic programming<br>Linear programming<br>Lyapunov drift | Fairness<br>Stability |

## 6. Conclusion

We have study the WSN scheduling with the different type of wireless sensor network scheduling. We have focus on wakeup scheduling in WSN schemes and obtained their study in Asynchronous Wakeup Scheduling, Heterogeneous Wake-up Scheduling, TDMA- Protocol-Scheduling, and Quorum-Based Wakeup Scheduling. All the wakeup scheduling patterns such as synchronized (SMAC) and staggered patterns (DMAC) are considered and we also introduced new efficient wakeup patterns such as crossed-ladders pattern which outperforms other methods. We also presented the new cross-layer idea, called multi- parent technique, where by assigning multiple parents with different wakeup schedules to each node in the network, significant performance improvement is achieved.

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