A Survey on Energy Efficiency in Wi-Fi

[1]Kavya Das .M, [2]Dileep V.K

[1]PG Scholar, [2]Assistant Professor
[1]Computer Science Department
[1]LBSITW, Trivandrum, India

Abstract: **The Major area which needs attention is the extension of network life which is dependent on utilization of battery with as much efficiency as possible. Wi-Fi has fairly high power consumption that limits the utilization of Wi-Fi in portable devices. Thus, current implementations turn off the Wi-Fi radio and perform periodic scans in order to discover new networks and devices. Various MAC protocols with different objectives have been proposed for wireless sensor networks. A thorough design of the medium access control (MAC) protocol is a key to reach a low power consumption. This paper mainly outlines the various MAC protocols followed by their advantages and disadvantages in the Wi-Fi circumstance.**

Index Terms— **Wi-Fi, Energy efficiency, Low duty cycle MAC protocols, Asynchronous wake up protocols, Efficient discovery.**

I. Introduction

As wireless sensor nodes usually rely on portable power sources such as batteries to provide the necessary power, their power management has become a crucial issue. The Wi-Fi technology is nowadays one of the most common ways to access the Internet. Today Wi-Fi is embedded in most of the portable devices. Despite its convenience, a factor that limits the utilization of Wi-Fi in portable devices is its impact on battery life. A meticulous design of the Medium Access Control(MAC) protocol is key to reach a low power consumption. MAC is an important technique that enables the successful operation of the network and avoids collisions from interfering nodes. There are many MAC protocols that have been developed for wireless voice and data communication networks. An energy efficient wireless MAC protocol must minimize the four sources of energy waste namely idle listening, overhearing, collisions and protocol overhead. It has been observed that idle energy plays an important role for saving energy in wireless sensor networks. Idle listening refers to the active listening to an idle channel, waiting for a potential packet to arrive. Most existing radios used in wireless sensor networks support different modes, like transmit/receive mode, idle mode, and sleep mode. In idle mode, the radio is not communicating but the radio circuitry is still turned on, resulting in the transmitting or receiving states. Thus, a better way is to shut down the radio as much as possible in idle mode [1].In order to save more idle energy, it is necessary to introduce a wake-up mechanism[2] for sensor nodes in the presence of pending transmissions. The major objective of a wake-up mechanism is to maintain network connectivity while reducing the idle state energy consumption. Existing wake-up mechanisms fall into three categories: on-demand wake-up [3], [4], [8], scheduled rendezvous [9], [5], and asynchronous wake-up [6],[7]. Overhearing refers to the reception of a packet, or of part of a packet, that is destined to another node. Collisions should of course be avoided as retransmissions cost energy. Finally, protocol overhead refers to the packet headers and the signalling required by the protocol in addition to the transmission of data payloads.

This paper is organized as follows: Section 2 gives the related protocols and mechanisms that have been developed in the context of energy efficiency in Wi-Fi and Section 3 gives the conclusion.

II. Literature review

Sensor-MAC (S-MAC)

S-MAC [9] is one of the base protocol which with slight modifications results in various protocols. S-MAC is having static sleep schedules. Basic concept of S-MAC is periodic sleep listen schedules which are handled locally by the sensor network. S-MAC protocol describes a system where sensors broadcast a wake up/sleep schedule. It reduces idle listening by periodically putting nodes into sleep state. The time period during which sensors are awake in S-MAC is fixed and data transmission occurs. Nodes which are adjacent, form clusters virtually and they share common schedule. This means that if two nodes are side by side and fall in two different clusters they wake up at listen schedule of both clusters. This also results in more energy consumption as nodes wake up to two different schedules. The schedules are also needed to be communicated to different nodes of virtual cluster which is accomplished by SYNC packets and time in which it is sent is known as synchronization period. To reduce control overhead S-MAC introduces coordinated sleeping among neighboring nodes. In addition to it, unicast data packets transmission is done using RTS/CTS.
Advantages: The battery utilisation is increased by implementing sleep schedules. This protocol is simple to implement and long messages can be efficiently transferred using message passing technique.

Disadvantages: RTS/CTS are not used due to broadcasting which may result in collision. SMAC has static sleep schedules that is schedule do not change according to need or changing environment which leads to sleep delay.

Timeout MAC (T-MAC)

T-MAC (Timeout MAC)[10] is the protocol which is derived from S-MAC protocol in which the non-sleep and sleep periods are fixed. The novel idea of T-MAC is to reduce idle listening .T-MAC improves energy efficiency by making sensors sleep only after a *fixed* timeout. In T-MAC the sensor node deviates to sleep period if no event has occurred. It transmits all messages in bursts of variable length, and sleeps between bursts. It makes the duration of the awake period adapt to the load in the channel, when no data has been received.

Advantages: T-MAC can easily handle variable load due to dynamic sleeping schedule.

Disadvantages: T-MAC's major disadvantage is early sleeping problem in which nodes may sleep as per their activation time and data may get lost especially for long messages. Also Periodic scanning results in higher duty cycles.

Asynchronous Low Duty Cycle MAC Protocols.

In synchronous MAC protocols[11] energy consumption of sensors are reduced by synchronizing the sensors' wakeup and sleep times. These protocols are not efficient in case of variable traffic rates because of fixed sleep times and listen times. S-MAC and T-MAC are example of synchronous MAC protocols. In Asynchronous MAC Protocols, synchronization is not required. And also it uses a simple technique to reduce the problem of idle listening with which all the cost of receiver is transferred to sender by using extended MAC header (preamble). By using this technique, nodes can check the channel periodically and the node can go to sleep state most of the time by saving energy.

a. B-MAC

B-MAC[11] is a configurable MAC Protocol for Wireless sensor networks.B-MAC protocol is a combination of CSMA and Low power listening (LPL) technique. Unsynchronized duty cycling is used in B-MAC with the long preambles to wake up the receivers. To increase the reliability of channel assessment B-MAC uses a filter technique. B-MAC also uses the adaptive preamble sampling and clear channel assessment (CCA) to minimize the problem of idle listening. In B-MAC each sensor is allowed to set an individual wake up/sleep schedule.

b. WiseMAC

WiseMAC [12] is a medium access control protocol designed for wireless sensor networks .WiseMAC improves upon the design of B-MAC by letting receivers advertise their sleep schedule .WiseMAC is based on the preamble sampling technique i.e regularly sampling the medium to check for activity. This protocol is based on non-persistent CSMA and uses the preamble sampling technique to minimize the power consumed when listening to an idle medium. The novel idea introduced by WiseMAC is to minimize the length of the wake-up preamble, exploiting the knowledge of the sampling schedule of one's direct neighbors. ***Sampling the medium***, means listening to the radio channel for a short duration. Transmitter only needs to generate a short preamble right before the next wake up event of the receiver.

Disadvantages: The long wake-up preambles cause a throughput limitation and a large power consumption overhead in transmission and reception. Since different receivers are active at different times, asynchronous MAC protocols are poorly suited for broadcast transmissions.

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Bluetooth Low Energy (BLE)

Bluetooth Low Energy (BLE)[13] is another technology that allows discovery with a reduced power consumption. Typically opportunistic networks use standard Bluetooth technology for discovery and synchronization. These works explore the nature of networks created by opportunistic contacts between people carrying mobile devices, and design protocols and algorithms to distribute data in these networks.

Disadvantages: BLE does not scale to large number of devices and is limited by its reduced range and data rates. BLE devices are not synchronized and therefore cannot afford long sleep intervals if they want to remain *discoverable*. .

Wi-Fi Direct

Wi-Fi Direct[14] is a new technology defined by the Wi-Fi alliance aimed at enhancing direct device to device communications in Wi-Fi. It allows Wi-Fi devices to discover each other and establish a direct connection without the presence of an Access Point(AP).Thus Wi-Fi Direct has to implement both the role of a client and the role of an AP. Direct device to device connectivity was already possible in the original IEEE 802.11 standard by means of the adhoc mode of operation.

Disadvantages: This requires a device doing discovery to remain always awake. Hence it is not energy efficient and results in significant discovery delays. It presents several drawbacks when facing nowadays requirements. Eg: lack of efficient power saving support and extended Qos capabilities.

III. CONCLUSION

An energy efficient wireless MAC protocol must minimize the four sources of energy waste. Various MAC protocols with different objectives have been proposed for wireless sensor networks. Current applications turn off the Wi-Fi radio and perform periodic scans in order to discover new networks and devices. In the context of Wi-Fi there should be mechanism to make the cluster discovery process energy efficient. Designing the system will have a wide set of challenges spanning from the lower communication layers upto higher levels. From the study it is to be noted that there is no standardized solution exists when devices are not connected to an Access Point(AP), which is very common for a portable device and to make it suitable for broadcast transmissions without an Access Point.

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