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ENERGY EFFICIENT PROTOCOLS IN WIRELESS NETWORKS

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***Abstract*-- This paper provides a comprehensive look at new and emerging energy efficient wireless protocols. A major consideration in designing these networks is energy efficiency and low power consumption. The benefits of each protocol are given. The types of wireless networks considered include Wireless Local Area Networks (WLANs), Wireless Personal Area Networks (WPANs), and Wireless Sensor Networks. Available Principles for performing power management in each of these networks are discussed, and their effective use is analyzed.**

***Index Terms*- Energy efficient protocols, energy efficiency, efficient wireless, sensor networks wireless networks, low power.**

I. INTRODUCTION

Wireless networks have had significant impact on the world specifically, on telecommunication. Many differences exist between wireless networks and tradition wired ones. The most notable difference between these networks is the use of the wired medium for communication. The promise of a truly wireless networks is to have the freedom to roam around anywhere within the range of the network and not be bound to a single location. Without proper power management of these roaming devices, however, the energy required to keep these devices connected to the network over extended periods of time quickly dissipates. This paper gives a brief explanation of many new and emerging wireless protocols. The energy efficiency techniques used by these technologies are given.

II. ENERGY CONTROLLED WIRELESS NETWORKS

Wireless networks have been a scorching topic for many years. Their potential was first realized with the deployment of cellular networks for use with mobile telephones in the late 1970's. Since this time, many other wireless wide area networks (WWANs) have begun to emerge, along with the introduction of wireless Metropolitan Area Networks (WMANs), wireless Local Area Network (WLANs), and wireless Personal Area Networks (WPANs). Table shows a number of standards that have been developed for networks.

Table: Standards for Wireless Networks

Features	PAN	LAN	MAN	WAN
Standards	**802.15 Bluetooth**	**802.11 Wi-Fi**	**802.16 Wimax**	**802.20 GSM,GPRS,CDMA 2.5G,3G,3.5G**
Speed	**<1 Mbps**	**11 to 54 Mbps**	**11 to 100+Mbps**	**10 to 384 Kbps 1.8/3,6-7.2 Mbps**
Range	**Small**	**Medium**	**Medium Long**	**Long**
Application	**Peer-to-peer Device-to-Device**	**Enterprise Network**	**Last Mile Access**	**Mobile Phone, Cellular Phone**

Energy consumption is important for each of these types of networks. Wireless sensor networks are specifically designed for very low power operation and thus deserve this degree of special attention. The following Fig. shows how these different types of networks compare in terms of data rate and power consumption range. The IEEE802.15.4 standard shown in the Figure is the one most widely used by wireless sensor networks.

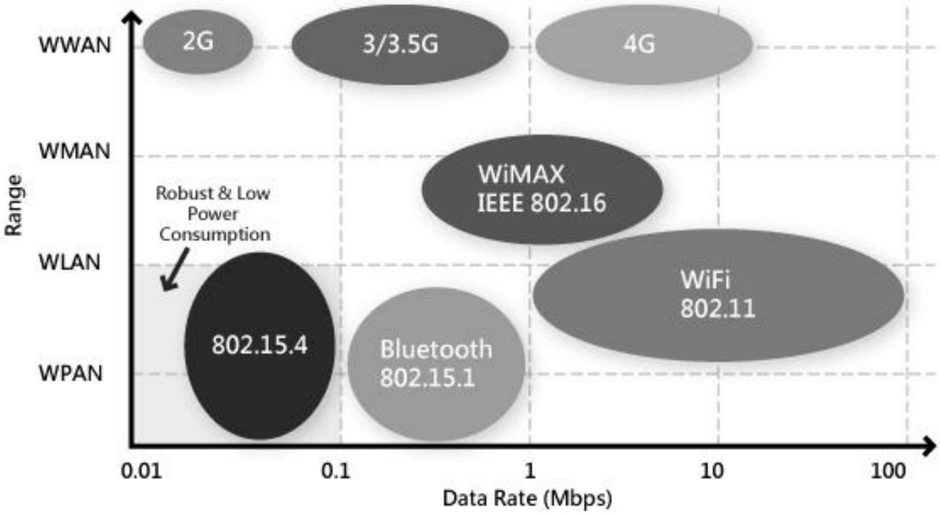

Fig: Energy Consumption in IEEE 802 based wireless networks.

A. Wireless LANs

Most wireless LANs are based on the IEEE 802.11 standard depicted in the above Figure and Table. This standard is known as Wi-Fi (Wireless Fidelity). Devices in these networks normally operate at a higher data rate than for devices existing in a WPAN. They are usually made to communicate over longer distances as well. Because of this higher data rate and higher communication range, they also tend to consume more power. To reduce the power consumed, a power management scheme known as PSM is built into the 802.11 standard.

B. Wireless PANs

PAN technology was primarily developed in order to allow personal devices to communicate wirelessly with one another. Devices in a PAN communicate within a much smaller range, and at a much lower data rate. The primary standards for WPANs include [IEEE 802.15.1] Bluetooth, [IEEE 802.15.3], and [IEEE 802.15.4] (Zigbee). While 802.15.3 operates at data rates comparable to those in an 802.11 WLAN, the range at which devices in these networks can communicate is much smaller. The IEEE 802.15.1 (Bluetooth) standard includes a energy efficiency scheme to further reduce the power consumption.

C. Wireless Sensor Networks

WSNs are made up of a large number of tiny low-cost, low-power, multi-functional devices used for taking out data from the environment around them. They are capable of taking sensor readings from the environment, processing that data, and communicating it back to some central location for further processing. As shown in Figure: 802.15.4 is not only the standard that consumes the least amount of power, but also the one having the lowest data rate.

III. PROTOCOLS DESIGNED TO REDUCING POWER CONSUMPTION

Wi-Fi and Bluetooth are two protocols that are widely used by portable electronics (telecommunication networks). Both have certain parts of their protocols designed to reducing power consumption. Wireless Sensor networks consist of sensors placed in remote areas to collect data and send it back to a base station.

A. Wireless Local Area Networks (WLAN)

Wi-Fi is certified based on the IEEE 802.11 standard that guarantees interoperability between certified components. The laptops and PDAs now come with Wi-Fi as a standard feature. Two methods in which Wi-Fi devices reduce energy consumption are: 1) Reducing retransmissions and 2) Entering sleep mode when network is not accessed. In sleep mode the device can save power without losing information. The sleeping device will periodically listen to network access point beacon frames. Beacon Interval is one of the router settings that are often talked about when trying to optimize wireless speed. Wi-Fi devices also use short control packets called “Request to Send” and “Clear to Send” before transmitting the long range data packets. The control packets reduce collisions because of their small size.

B. Wireless Personal Area Networks (WPAN)

Bluetooth sleep modes are used to reduce the power consumption (extend the battery life) and to free the Piconet of device activity so other devices may participate in the Piconet. Bluetooth sleep modes include short one-time hold periods, periodic sniff periods, and long time park periods. **Hold Mode** is a temporary process that is typically entered into by a device when there is no need to send voice or data information for a relatively long period time. **Sniff Mode** is a process of listening for specific types of commands that occur periodically. Bluetooth sniff mode is used to reduce the power consumption of the device as the receiver can be put into standby between sniff cycles. **Park Mode** is the process of temporarily deactivating a device to allow its active member address to be removed (probably re-assigned) and assigning communication functions to **remain inactive for extended periods of time**. The maximum time period that can be assigned for hold, sniff, or park sleep mode is 65,440 slots (approximately 40 seconds).

C. Wireless Sensor Networks (WSN)

WSNs generally have battery operated sensor nodes that focus on finding the best energy efficient protocols for these networks. The part of the node that consumes the most energy is often the radio module. One of the challenges in designing a wireless sensor network is that sensors are organized into a multi-hop wireless network that must be able to function properly for long periods of time on limited power supplies. Types of sensor networks used are:

a) In Two-layered heterogeneous sensor network, two types of nodes are deployed: 1) the basic sensor nodes and 2) The cluster head nodes. The basic sensors nodes are simple nodes and have limited power supplies. They perform the sensing task. The cluster head nodes are much more powerful and focus on communications and computations. They organize the basic sensors around them into a cluster that only communicates with the cluster node.

b) In Direct voting sensor networks, the witness node transmits the vote directly to the base station. This method of voting performs better in terms of information assurance, overhead and delay than having the votes transmitted to the base station by the cluster node. In this, only one copy of the correct fusion result needs to be sent to the base station. The base station can terminate the voting process when the threshold of agree or disagree votes has been received.

c) In Classification of Signals in Sensor Networks , Instead of sending the entire stream of raw data, the sensor nodes select a subset of data from the detected signals, classify those data, then send only the classification results to the base station. The sensor nodes have limited energy, memory, and processing capabilities, so the classification algorithm has to be a high-accuracy low complexity algorithm.

d) In Turn off redundant Nodes, the sensors should schedule their sensing and sleeping times to minimize the overall awake time of the sensors while ensuring that the entire network neighborhood is completely covered.

e) Quorum scheme and the home-agent scheme, is used to produce a high probability that both the ADV and REQ messages will meet at a rendezvous node without using any type of flooding or broadcasting. In the quorum scheme, all ADV messages are propagated north and south creating a vertical line of nodes that receive the ADV message. Similarly, all REQ messages are propagated east and west through the network creating a horizontal line of nodes that receive the REQ message. In the home-agent scheme, the sensor nodes need to know the location of the center of the network. All ADV and REQ messages are sent to the center of the network.

f) CMAC begins with an unsynchronized duty cycle using "anycast" and converges to a synchronized "unicast" once an optimal forwarding node is found. Once the best node has been found, the transmitting node can converge from anycasting its packets to all nodes, to unicasting to the node it knows is route optimal.

g) In Pattern MAC (PMAC), a nodes "pattern" is its tentative sleep-wake up plan where a 0 indicates sleep and a 1 indicates awake. At first nodes exchange their patterns for a period of communication. Then nodes decide their actual sleep-wake up schedule based on their pattern and the patterns of their neighbors.

h) Deterministic Energy-Efficient Protocol for Sensor Networks (DEEPS), increases sensor network lifetime by using distributed algorithms for continuous and event-driven sensor network models. If a target is found to have the lowest growing battery power left to cover it, then it is covered by a single sensor with the largest battery power. DEEPS scheduling method can almost double the total network lifetime compared to algorithms that only look at individual sensor's battery power.

IV. ENERGY SAVING TECHNIQUES AT DIFFERENT LAYERS

The differences between each type of network were introduced with an emphasis put on their requirements for performing power management that each of them have. Power management techniques used by these standards for reducing the power consumed in each type of network.

A. Application Layer

At the application layer a number of different techniques can be used to reduce the power consumed by a wireless device. A technique known as **load partitioning** allows an application to have all of its power intensive computation performed at its base station rather than locally. Another technique uses **proxies** in order to inform an application to changes in battery power. For **database systems**, techniques are explored that are able to reduce the power consumed during data retrieval, indexing, as well as querying operations. In all three cases, energy is conserved by reducing the number of transmissions needed to perform these operations. For **video processing** applications, energy can be conserved using compression techniques to reduce the number of bits transmitted over the wireless medium.

B. Transport Layer

The various techniques used to save energy at the transport layer all try to reduce the number of retransmissions necessary due to packet losses from a faulty wireless link. In a wireless network, however, losses can occur from time to time and should not immediately be interpreted as the onset of blocking. The **TCP-Probing** and **Wave and Wait Protocols** have been developed to guarantee end-to-end data delivery with high throughput and low power consumption.

C. Network Layer

Power management techniques existing at the network layer are concerned with performing power efficient routing through a multi-hop network. They are typically backbone based**, topology control** based, or a hybrid of them both. In a backbone based protocol, some nodes are chosen to remain active at all times (backbone nodes), while others are allowed to sleep periodically. Any node in the network must therefore be within one hop of at least one backbone node, including backbone nodes themselves. Energy savings are achieved by allowing non-backbone nodes to sleep periodically, as well as by periodically changing which nodes in fact make up the backbone.

D. Data Link Layer

The two most common techniques used to conserve energy at the link layer involve reducing the transmission overhead during the **Automatic Repeat Request (ARQ)** and **Forward Error Correction (FEC)** schemes. Both of these schemes are used to reduce the number of packet errors at a receiving node. By enabling ARQ, a router is able to automatically request the retransmission of a packet directly from its source without first requiring the receiver node to detect that a packet error has occurred. Integrating the use of FEC codes to reduce the number of retransmissions necessary at the lower transmission power can result in even more energy savings. By scheduling multiple packet transmission to occur back to back, it may be possible to reduce the overhead associated with sending each packet individually.

E. MAC Layer

MAC layer consist "sleep scheduling" protocols. The basic principle behind all sleep scheduling protocols is that lots of power is wasted listening on the radio channel while there is nothing there to receive. Sleep schedulers are used to duty cycle a radio between its on and off power states in order to reduce the effects of this **idle listening.** They are used to wake up a radio whenever it expects to transmit or receive packets and sleep otherwise. Other power saving techniques at this layer include battery aware MAC protocols (BAMAC) in which the decision of who should send next is based on the battery level of all surrounding nodes in the network.

F. Physical Layer

At the physical layer, proper hardware design techniques allow one to decrease the level of parasitic leak currents in an electronic device to almost nothing. These smaller leakage currents ultimately result in longer lifetimes for these devices, as less energy is wasted while idle. A technique known as **Remote Access Switch (RAS)** can be used to wake up a receiver only when it has data intended to it. Energy harvesting techniques allow a device to actually gather energy from its surrounding environment. Ambient energy is all around in the form of vibration, strain, inertial forces, heat, light, wind, magnetic forces, etc.

IV. SUMMARY

In this survey, a variety of different energy conserving techniques for wireless networks have been explored. Although the scope of this paper has been limited exclusively to WLANs, WPANs, and Wireless Sensor Networks: many of the techniques presented are universal and can be used to perform power management in any type of network. In conclusion, if energy efficiency is a major component in a wireless network design, then many new protocols can be examined to aid in the networks design. However, these energy efficient designs may increase the initial hardware cost of the network. It was shown that while WLANs and traditional WPANs may achieve longer lifetimes through the use of the power management techniques presented, low power design in WSNs is an essential feature and thus required particular focus in this paper.

It has been shown that the current research being conducted for power management in wireless networks has been focused developing better topology maintenance protocols, sleep scheduling protocols techniques. While each of these techniques provides power savings on their own, they can all be combined to achieve better performance than any one of them individually.

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