IMPROVMENT OF ROUTING PROTOCOL IN WIRELESS SENSOR NETWORK FOR ENERGY CONSUMPTION TO MAXIMIZE NETWORK LIFETIME

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ABSTRACT

Wireless Sensor Networks (WSNs) consist of thousands of tiny nodes having the capability of sensing, computing, and wireless communications. Many routing, power management, and data dissemination protocols have been specifically designed for WSNs where energy consumption is an essential design issues. Due to energy constraints, the deployment and maintenance of WSNs should be easy and scalable to maintain the network lifetime.

A comprehensive energy efficient hierarchical cluster-based routing protocol was proposed for continuous stream queries in wireless sensor network. The routing scheme and algorithm has the common objective of trying to extend the lifetime of the sensor network. We introduce cluster head-set idea for cluster-based routing where several clusters are formed with the deployed sensors to collect information from target field. On rotation basis, a head-set member receives data from the neighbour nodes and transmits the aggregated results to the distance base station.

For a given number of data collecting sensor nodes, the number of control and management nodes can be systematically adjusted to reduce energy consumption quite significantly and prolongs the life time of sensor network. This document is a study about hierarchical cluster-based routing protocol algorithm where the implementation was done using Matlab simulator to study the performance of this algorithm in term of lifetime.

We show that existing energy models over-estimate life expectancy of a sensor node by 30–58% and also yield an “optimised” number of clusters which is too large. Simulation results show that our hierarchical clustering protocol balances the energy consumption well among all sensor nodes and achieves an obvious improvement on the network lifetime.

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LIST OF ABBREVIATIONS

WSN	-	Wireless Sensor Network
SIR	-	Signal to Interference Ratio
DCS	-	Digital cellular system
CDMA	-	Code Division Multiple Access
MT	-	Mobile Terminal
BS	-	Base Station
IS	-	Interim Standard
DS	-	Direct Sequence
TDMA	-	Time Division Multiple Access
RCC	-	Random competition based clustering
SN	-	Sensor Node
FDMA	-	Frequency Division Multiple Access
ADC	-	Analog Digital Converter
SYNC	-	Synchronization Period
DSMAC	-	Dynamic Sensor-MAC
CSMA	-	Carrier Sensor Multiple Access
SPIN	-	Sensor Protocols for Information Via Negation
GBR	-	Gradient Based Routing
IDSQ	-	Information Driven Sensor Querying
CADR	-	Constrained Anisotropic Diffusion Routing
CH	-	Cluster Head
GAF	-	Geographic Adaptive Fidelity
GEAR	-	Geographic and Energy Aware Routing
SAR	-	Sequential Assignment Routing
AWE	-	Single Winner
MWE	-	Multiple Winner

MANETS	-	Mobile Ad Hoc Network
LEACH	-	Low-Energy Adaptive Clustering Hierarchy
RAM	-	Random Access Memory
ms	-	meli second
EEPROM	-	Electronically Erasable Programmable Read Only Memory
OSI	-	Open Systems Interconnection
GPS	-	Global Positioning System

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CHAPTER I

INTRODUCTION

1.1 Overview

With the advance of technology, computers can be built in small size while still maintaining the capability of data processing and communication. A good example is the wireless sensor platform. A typical sensor node usually has a size close to a coin or even smaller, including the battery. It integrates the computing system, the radio component and the sensing units together on a single tiny platform.

The advancement in technology has made it possible to have extremely small, low powered devices equipped with programmable computing, multiple parameter sensingand wireless communication capability. Also, the low cost of sensors makes it possible to have a network of hundreds or thousands of these wireless sensors, thereby enhancing the reliability and accuracy of data and the area coverage as well. Also, it is necessary that the sensors be easy to deploy (i.e., require no installation cost etc). Protocols for these networks must be designed in such a way that the limited power in the sensor nodes is efficiently used. In addition, environments in which these nodes operate and respond are very dynamic, with fast changing physical parameters.

Since WSNs consist of numerous battery-powered devices, the energy efficient network protocols must be designed.

In conventional methods, sensor networks are composed of thousands of resource constrained sensor nodes and also some resourced base stations are there. All nodes in a network communicate with each other via wireless communication. Moreover, the energy required to transmit a message is about twice as great as the energy needed to receive the same message. The route of each message destined to the base station is really crucial in terms network lifetime: e.g., using short routes to the base station that contains nodes with depleted batteries may yield decreased network lifetime. On the other hand, using a long route composed of many sensor nodes can significantly increase the network delay.

But, some requirements for the routing protocols are conflicting. Always selecting the shortest route towards the base station causes the intermediate nodes to deplete faster, these results in a decreased network lifetime. At the same time, always choosing the shortest path might result in lowest energy consumption and lowest network delay.

Finally, the routing objectives are tailored by the application; e.g., real-time applications require minimal network delay, while applications performing statistical computations may require maximized network lifetime. Hence, different routing mechanisms have been proposed for different applications. These routing mechanisms primarily differ in terms of routing objectives and routing techniques, where the techniques are mainly influenced by the network characteristics.

To overcome energy efficient and improve the recovery from wireless sensor network there are several energy efficient communication models and protocols that are designed for specific applications, queries, and topologies. The routing algorithm proposed in this research is suitable for continuous monitoring of numerous widespread sensors, which are at a large distance from the base station. This research will explain our hierarchical cluster-based routing protocol, about how works perform quantitative analysis for our protocol and apply in Matlab to see the results obtained and evaluate the performance of the proposed protocol.

1.2 Problem Statements

The main problem in today wireless communications is to design wireless sensor network in which the energy consumption in sleep mode; be it hardware or software and should be solved in order for the protocol to achieve the desired network lifetime.

The problem in the traditional routing protocols are not well suited due to adjacent nodes may have similar data. So, rather than sending data separately from each node to the requesting node, it is desirable to aggregate similar data and send it.

In traditional wired and wireless networks, each node is given a unique id, used for routing. This cannot be effectively used in sensor networks. This is because, these networks being data centric, routing to and from specific nodes is not required.

The number of control and management nodes could not be acclimatized with the network environment. So, the sensor cannot be obtained the suitable state to be more of the time in sleep model when there is no signal.

This protocol explains how the routing algorithm proposed work to be suitable for continuous monitoring of numerous widespread sensors, which are at a large distance from the base station.

The results using Matlab are shown to see the energy consumption and the time estimation with respect to cluster diameter and the head set size.

1.3 Project Objectives

The objectives of this project are:

i. To Simulate wireless sensor network system based on a new approach method by using Matlab.
ii. Reduce the energy consumption.
iii. To design and develop a communication protocol which increases the network lifetime.

iv. To efficiently disseminate query and query results into the network.
v. To control and manage nodes according to the environment.

1.3 Project Scopes

The scopes of this project have various strategies such as:

i. Performance assurance & optimization module.

Protocol design to optimize the system current performance as to how the energy consumption is low duty sleep model and also the communication protocol. This module is responsible to adjust the network configuration and parameters, such like link weight, to achieve better energy utility and satisfy with the given constraints and capacity constraints.

ii. Routing algorithm protocol.

Developing the routing algorithm protocol command software for specific application, queries, and topologies. The hierarchical cluster-based routing schemes and algorithms have the common objective of trying to get better throughput and to extend the lifetime of the sensor network.

iii. Simulation and verification.

This algorithm is simulated and verified using Matlab. Performing quantitative analysis for our protocol and evaluating the performance of the proposed protocol was observed.

CHAPTER II

LITERATURE REVIEW

2.1 History of wireless communication

The history of wireless communications began in 1886 when H. Hertz generated and, thus, proved the presence of J. C. Maxwell's theoretically predicted electromagnetic waves. In the following year G.Marconi showed the possible of wireless communications, as clearly documented by the words delivered before the Royal Institution in 1897 from the Technical Director of the British Post Office, who supported G. Marconi:

"It is curious that hills and apparent obstructions fail to obstruct... Weather seems to have no influence; rain, fogs, snow and wind, avail nothing... The distance to which signals have been sent is remarkable. On Salisbury Plain Mr. Marconi covered a distance of four miles. In the Bristol Channel this has been extended to over eight miles and we have by no means reached the limit. It is interesting to read the surmises of others. Half a mile was the wildest dream."

In 1901 G. Marconi established a radio connection over the Atlantic. Sequence results, research and development to use one of the most widely applications in the wireless communication system, that of radio broadcasting. Using this medium, G. Marconi in 1937, said in a radio message:

“Radio broadcasting, however, despite the great importance reached and the still unexplored fields open to investigation, is not, in my opinion, the most significant application of modern Communications, because it is a one way communication only. Greater importance is related, in my opinion, to the possibility offered by radio of exchanging communications anywhere the correspondents are located, in the middle of the ocean, in the ice pack in the pole, in the desert plains or over the clouds in an airplane."

These words should prove to be true and one hundred years after G. Marconi's first experiments, the market of wireless mobile communications with duplex transmission is one of the fastest expanding of the world. The establishment for a widespread of wireless mobile communications was laid with the standardization of the first generation cellular mobile radio systems in the 1980s. The origins of digital communications go back to the work of S. Morse in 1837, demonstrating an electrical telegraphy system. The so-called Morse code represents the letters of the alphabet by sequences of dots and dashes and was the major of modern variable-length source coding.

The rapid development in the area of microelectronics with a continuous increase in device density of integrated circuits and the development of low-rate digital speech coding techniques made completely digital second generation cellular mobile radio systems created. Various second generation cellular systems were developed in the 1990s. Most of these systems use Time Division Multiple Access (TDMA), such as the Global System for Mobile Communications (GSM) and the Digital Cellular System 1800 (DCS1800) in Europe, the Interim Standard (IS-54) in the USA, and the Personal Digital Cellular (PDC) system in Japan. With TDMA, the time axis is subdivided into different non-overlapping time slots where each user has time slot; TDMA is combined with Frequency Division Multiple Access (FDMA) to reduce the hardware complexity of an otherwise extremely broadband system and to increase the flexibility of the system.

(Heinzelman et al., 2000) describes the LEACH protocol, which is a hierarchical self-organized cluster-based approach for monitoring applications. The data collection area is randomly divided into several clusters. Based on Time Division Multiple Accesses (TDMA), the sensor nodes transmit data to the cluster heads, which aggregate and transmit the data to the base station. A new set of cluster heads are chosen after specific time intervals. A node can be re-elected only when all the remaining candidates have been elected.

Parallel to the TDMA based second generation standards, the IS-95 was developed in the USA, used Code Division Multiple Access (CDMA) with direct sequence (DS) spectrum spreading, and combined with FDMA. The origins of CDMA go back to the beginnings of spread spectrum communications in the first half of the 20st century (Gilhousen et al., 1991).

Primary applications of spread spectrum communications put in the development of secure digital-communication systems for military use. Since the second half of the 21st century, spread spectrum communications became of great interest also for commercial applications, including mobile multi-user Communications.

In 1981, Baker and Ephremides proposed a clustering algorithm called "Linked Cluster Algorithm (LCA)" (Baker and A. Ephremides, 1981) for wireless networks. To enhance network manageability, channel efficiency and energy economy of MANETS, clustering algorithms have been investigated in the past. Lin and Gerla investigated effective techniques to support multimedia applications in the general multi-hop mobile ad-hoc networks using CDMA based medium arbitration in (C.R. Lin and Gerla, 1997). Random competition based clustering (RCC) (K. Xu and Gerla, 2002) is applicable both to mobile ad hoc networks and WSN. RCC mainly focuses at cluster stability in order to support mobile nodes.

Cluster-based approaches are suitable for habitat and environment monitoring, which requires a continuous stream of sensor data. Directed diffusion and its variations are used for event-based monitoring. (Intanagonwiwat et al., 2000) describes a directed diffusion protocol where query (task) is disseminated into the network using hop-by-hop communication. When the query is traversed, the gradients (interests) are established for the result return path. Finally, the result is routed using the path based on gradients and interests. (Braginsky and Estrin, 2002), a variation of directed diffusion, use rumor routing to flood events and route queries; this approach is suitable for a large number of queries and a fewer events.

(Ye et al., 2004) describe a contention-based medium access protocol, S-MAC, which reduces energy consumption by using virtual clusters. The common sleep schedules are developed for the clusters. Moreover, in-channel signalling is used to avoid overhearing. (Cerpa and Estrin, 2004) propose ASCENT that operates between routing and link layers. Any routing or data dissemination protocol can use ASCENT to manage nodes redundancy. In ASCENT, nodes monitor their connectivity and decide whether to become active and participate in the multihop networking. Moreover, nodes other than active nodes remain in passive state until they get a request from active nodes.

As an extension of LEACH (Heinzelman et al., 2000), our proposed protocol introduces a head-set for the control and management of clusters. Although S-MAC (Ye et al., 2004) divides the network into virtual clusters, the proposed protocol divides the network into a few real clusters that are managed by a virtual cluster-head.

2.2 Wireless Sensor Networks (WSN)

According to definition given in (Sohraby et al., 2007), “A wireless sensor networks (WSNs) consists of densely distributed nodes that support sensing, signal processing, embedded computing, and wireless connectivity; sensors are logically linked by self-organizing means. WSN typically transmit information to collecting (monitoring) stations that aggregate some or all of the information. WSN have unique characteristics, such as, but not limited to power constraints and limited battery life for the WNs, redundant data acquisition, low duty cycle, and, many-tooneflows.” Although the development of this kind of networks was initially for military applications, but nowadays they are used in many different industrial and civilian application areas, including industrial process monitoring and control, healthcare applications or traffic control. WSNs are composed of a set of sensor nodes, typically equipped with some sensors, a radio transceiver or other wireless communications device, a small microcontroller, and an energy source, usually a battery. Therefore, these devices make up a network with sensing, data processing and routing capabilities.

Advantages of wireless sensor networks knowing about the advantages of WSNs, it is enough to be conscious of the wide variety of applications where WSNs are present, typically, WSNs applications involved in some kind of monitoring, tracking, or controlling. Some of the numerous applications and the benefits that WSNs bring are:

i. Environmental Monitoring: watershed management, forest fire prediction or irrigation management. It helps to preserve and maintain the natural resources.

ii. Structural Health and Industrial Monitoring: machinery failure detection. It reduces the maintenance costs and prevents from catastrophic failures.

iii. Civil Structure Monitoring: health monitoring of large civil structures, like bridges or skyscrapers. It prevents from human catastrophes.

iv. Medical Health-Care: telemedicine, remote health monitoring. Allows doctors in remote and rural areas to consult with specialists in urban areas, remote handling medical equipment (tele-surgery), etc.

2.2.1 Drawbacks of wireless sensor networks

Although WSNs offer many advantages in a numerous application, there are several constraints which will affect directly the networks and devices' design. Some of the most significant constraints are:

i. Power consumption: this constraint affects directly on the nodes'operating lifetime. With energy-aware and transmitting power adjusting capacity protocols, the energy consumption can be highly reduced, and thus increased the network lifetime.

ii. Self-configuration capability and good scalability: this issue can be solved by choosing and implementing the suitable network protocol.

iii. Fault tolerance: if all the devices process the same signal (temperature, humidity, etc.), the network will offer replication in a native manner. If the devices do not develop the same function, the device replication can solve the fault tolerance problem, and this solution shouldn't affect the scalability due to the nature of the network.

This thesis proposed a mechanism to will counter the first drawback of WSNs which is the power consumption by designing and implementing the appropriate algorithm in a routing protocol.

2.3 Wireless Sensor Network Model

Unlike their ancestor ad-hoc networks, WSNs are resource limited, they are deployed densely, they are prone to failures, the number of nodes in WSNs is several orders higher than that of ad hoc networks, WSN network topology is constantly changing, WSNs use broadcast communication mediums and finally sensor nodes don't have a global identification tags (Karpand K, 2000). The major components of a typical sensor network are:

- Sensor Field: A sensor field can be considered as the area in which the nodes areplaced.
- Sensor Nodes: Sensors nodes are the heart of the network. They are in charge of collecting data and routing this information back to a sink.
- Sink: A sink is a sensor node with the specific task of receiving, processing and storing data from the other sensor nodes. They serve to reduce the total number of

messages that need to be sent, hence reducing the overall energy requirements of the network. Sinks are also known as data aggregation points.

- Task Manager: The task manager also known as base station is a centralised point of control within the network, which extracts information from the network and disseminates control information back into the network. It also serves as a gateway to other networks, a powerful data processing and storage centre and an access point for a human interface. The base station is either a laptop or a workstation.

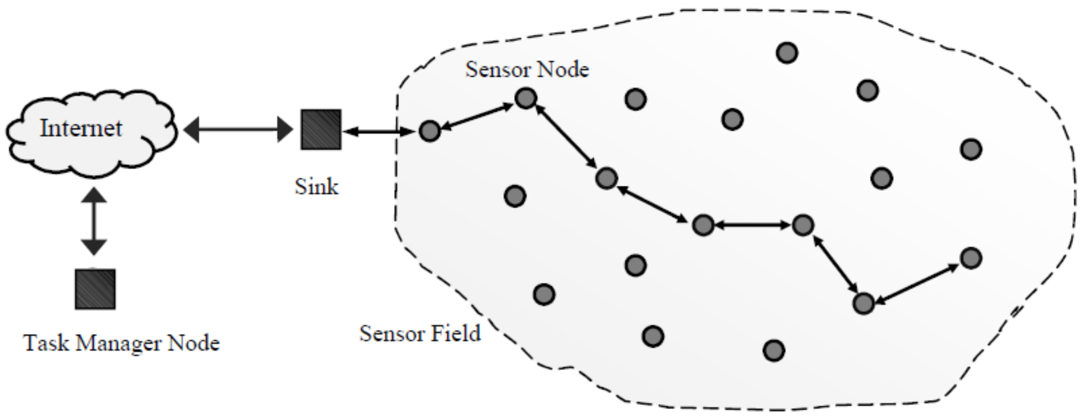

Figure 2.1: Components of Wireless Sensor Networks

Data is streamed to these workstations either via the internet, wireless channels, satellite etc. So, hundreds to several thousand nodes are deployed throughout a sensor field to create a wireless multi-hop network. Nodes can use wireless communication media such as infrared, radio, optical media or Bluetooth for their communications. The transmission range of the nodes varies according to the communication protocol is used.

A Sensor Node is a small device that has a micro-sensor technology, low power signal processing, low power computation and a short-range communications capability. A typical sensor node usually consists of a sensing unit, a processing unit, a communication unit and a power unit as shown in Figure 2.2.

The sensing unit senses and converts the signal from analog to digital via the Analog Digital Converter (ADC), location finding systems, mobilizers that are required to move the node in specific applications and power generators. The analog signals are measured by the sensors are digitized via an ADC and in turn fed into the processor. The processing unit processes and stores the data. It is the core of the sensor node and is responsible for the management of the whole platform. The processor and its associated memory commonly RAM is used to manage the procedures that make the sensor node carry out its assigned sensing and collaboration tasks. Memories like EEPROM or flash are used to store the program code. The communication unit transmits and receives data to and from the network. The radio transceiver connects the node with the network and serves as the communication medium of the node.

The power unit provides the energy for other units. The power supply/battery is the most important component of the sensor node because it implicitly determines the lifetime of the entire network. Due to size limitations of AA batteries or quartz, cells are used as the primary sources of power.

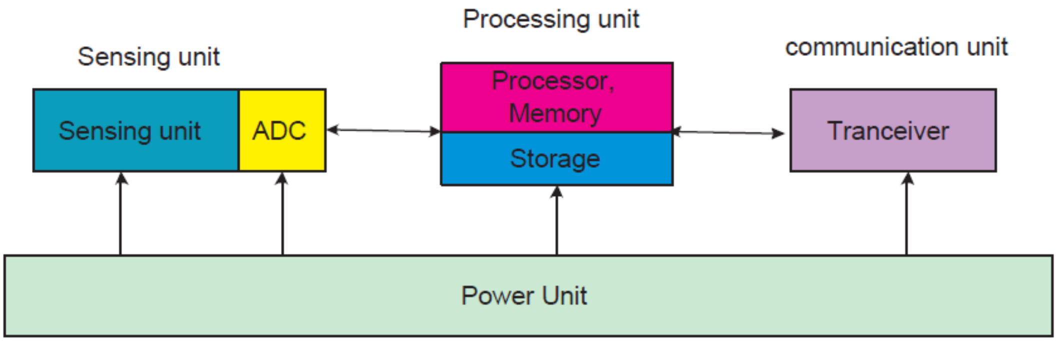

Figure 2.2 Typical components of a sensor node

2.4 Protocol architecture

Protocol architecture is the layered structure of hardware and software that support the exchange of data between two systems. When communication is desired among computers from different vendors, the data must be transmitted in the specific format because different vendors use different data format and data exchange protocols. The key functions normally performed by a protocol include encapsulation, segmentation and reassembly, connection control, ordered delivery, flow control, error control, addressing and multiplexing. There are two protocol architecture have served as the basis for the protocol standards which is TCP/IP and OSI model (Stalling, 2004). As shown below the Figure 2.3 indicates the different between TCP/IP and OSI model.

<table>
<tr><th>TCP/IP</th><th>OSI</th></tr>
<tr><td rowspan="3">Application</td><td>Application</td></tr>
<tr><td>Presentation</td></tr>
<tr><td rowspan="2">Session</td></tr>
<tr><td rowspan="2">Transport (host-to-host)</td></tr>
<tr><td>Transport</td></tr>
<tr><td>Internet</td><td rowspan="2">Network</td></tr>
<tr><td rowspan="2">Network Access</td></tr>
<tr><td>Data Link</td></tr>
<tr><td>Physical</td><td>Physical</td></tr>
</table>

Figure 2.3: A comparison of the OSI and TCP/IP protocol architecture

2.4.1 OSI model

OSI model was developed by ISO which would allow the exchange of data between various platforms of different vendors. It has seven layers where each layer performs a certain internetworking function. The function of each layer described as follows:

i. Physical Layer: Transmits the bit stream over the physical medium.
ii. Data Link Layer: Provide reliable transfer of information.
iii. Network Layer: Provides transmission & switching technologies.
iv. Transport Layer: End-to-end error recovery and flow control.
v. Session Layer: Establishes, manages & terminates connections.
vi. Presentation Layer: Represent the data.
vii. Application Layer: Provides access to the OSI environment for users.

2.4.2 TCP/IP protocol architecture

The TCP/IP model organizes the communication task into five relatively independent layers:

i. Physical Layer: Physical interface between a data transmission device (e.g. computer) and a transmission medium or network. This layer concerned with the characteristics of transmission medium, signal level and data rates.
ii. Network Access Layer: Perform the data exchange between end systems. The destination addresses provision so that the network can send the data to the appropriate destination.
iii. Internet Layer: Provides the routing function across multiple networks. This function is unimplemented in the end system and routers.
iv. Transport Layer: This layer concerned on end-to-end data transfer. The Transmission Control Protocol (TCP) is the most commonly used protocol to perform this functionality.
v. Application Layer: Support user application for example http, smtp and fttp.

2.5 MAC protocol

The MAC layer is a sub-layer of the data link layer and it is used in networks where multiple machines need to communicate via a single communication channel. MAC layer must be energy-efficient to improve the network lifetime which become the main objectives of current research and study. In (Ye et al., 2001), there are several causes of energy waste concerning MAC layer. There are collisions, overhearing, control packet overhead, idle listening and over emitting. Collisions consist on the reception of more than one packet at the same time which resulted in packets being dropped and retransmission was initiated.

Overhearing occurs when a node receives packets destined to other nodes. The control packet overhead or the number of control packets should be minimized as far as possible in a data transmission. Idle listening is produced when a node listens to an idle channel to receive possible traffic. On the other hand, over emitting is caused by the transmission of a message when the destination node is not ready. A correctly designed MAC protocol should avoid these facts in order to obtain the best performance and minimum energy consumption. A survey done by (Demirkol, 2006) presented the advantages and disadvantages of several MAC protocols. These protocols are:

i. Sensor-MAC (S-MAC)

The basic idea of this MAC protocol consists on locally managed synchronizations and periodic sleep listen schedules based on these synchronizations. Nodes sleep and wake up periodically introducing the term of duty cycle. This MAC protocol shows a disadvantages when two neighbour nodes reside in two different virtual clusters which set up a common sleep schedule, they wake up at listen periods of both clusters. Schedule exchanges are accomplished by periodical SYNC packet broadcasts to immediate neighbours. The period for each node to send a SYNC packet is called the synchronization period. A sample of sender-receiver communication is shown in Figure 2.4. Collision avoidance is achieved by a carrier sense, RTS/CTS packet exchanges prevent from the hidden node problem, and adaptive listening can be used in order to reduce the sleep relay and thus the overall latency.

The advantages of this MAC protocol, includes the implementation simplicity and its reduced energy consumption through sleep schedules. Besides, there are other disadvantages which are the increment of collision probability when broadcasting does not use RTS/CTS, the efficiency loss with its constant and predefined sleep and listen periods, overhearing and idle listening problems.

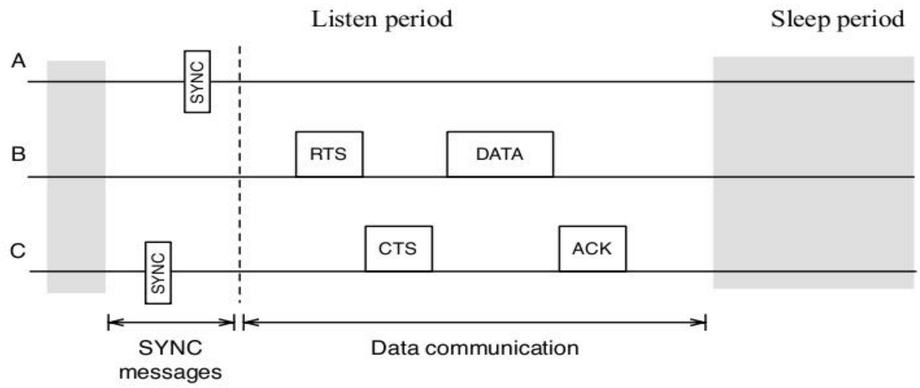

Figure 2.4: SMAC messaging scenario (Ye et al., 2001)

ii. Wireless sensor MAC (WiseMAC)

This protocol is spatial TDMA and CDMA with preamble sampling technique. Data channel is accessed with TDMA method, whereas the control channel is accessed with CSMA method. All network nodes sample with a common media period, but using independent relative schedule offsets. They initialize the preamble with the same sampling period's length. During the protocol's use, after waking and sampling the media when a node reaches an it's occupied, stays hearing until receives a packet or finds free the media. This protocol has over emitting problems when after the preamble due to reason like interference, the receiver is not available. WiseMAC offers a method to dynamically determine the length of the preamble to reduce the power consumption. That method uses the knowledge of the sleep schedules of the transmitter node's direct neighbours. The drawbacks of wiseMAC are the difficult of broadcast communication due to the decentralized duty cycle planning and the hidden terminal problem apparition are the main inconvenient. Figure 2.5 shows the wiseMAC concept.

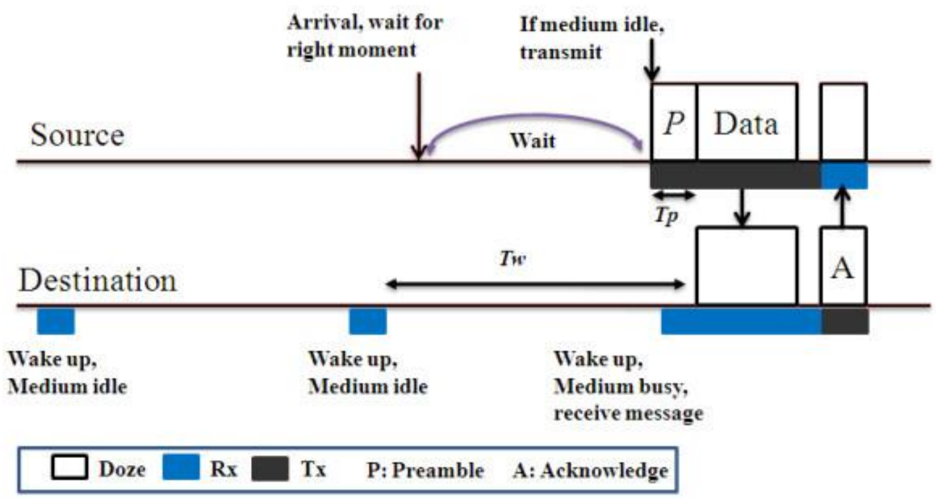

Figure 2.5: WiseMAC concept (Demirkol, 2006)

vi. Traffic-Adaptive MAC Protocol (TRAMA)

TRAMA is a TDMA-based algorithm and proposed to increase the utilization of classical TDMA in an energy-efficient manner (Demirkol, 2006). In TRAMA protocol, a distributed election algorithm is used in order to select a sender inside a two-hop neighbourhood. By means of this mechanism, the hidden terminal problem is eliminated and nodes inside the one hop neighbourhood guarantee no collision packets will be received. In this registry, time is divided in two different transmission periods which are random-access periods, where two-hop topology information through contention-based channel access, and scheduled-access. In these last ones, slots which will be used by nodes are announced by a schedule packet and the bitmap message scheduled receivers. The advantages of TRAMA are higher percentage of sleep time and less collision probability is achieved compared to CSMA based protocols. Meanwhile, disadvantages are transmission slots are set to be seven times longer than the random access period. Even so, TRAMA duty cycle is at least of 12.5%, a considerable high value.

vii. SIFT

This protocol is proposed for event-driven sensor network environment (Demirkol, 2006). The main idea of this protocol is when an event is sensed, the first R of N potential reports is the most crucial part of messaging and has to be relayed with low latency. SIFT uses a non-uniform probability distribution function. This function helps to the slot acquisition within the slotted contention window: if nodes don’t transmit on the first window slot, all nodes increment exponentially its transmission probability on the next slot considering limited the number of competitors.

One of advantages in this MAC protocol is very low latency is achieved with many traffic sources. This parameter can be set properly to the environment requirements. Thus, it could be possible to obtain a power consumption decrement losing some features as low latency when network life time is the main objective. One of the main drawbacks is increased idle listening caused by listening to all slots before sending as well as overhearing.

iv. DMAC

The purpose of this protocol is to achieve very low latency, but still to be energy efficient. This protocol makes use of a converge cast communication pattern within sensor network where unidirectional paths from the possible sources to the BS can be represented with data gathering trees. The data gathering tree and implementation of DMAC is shown in Figure 2.6. During a node reception period, all its sensor nodes have also the same transmission period and they compete for the media. Thus, this protocol provides low latency by assigning contiguous slots to the consecutive nodes along the transmission path.

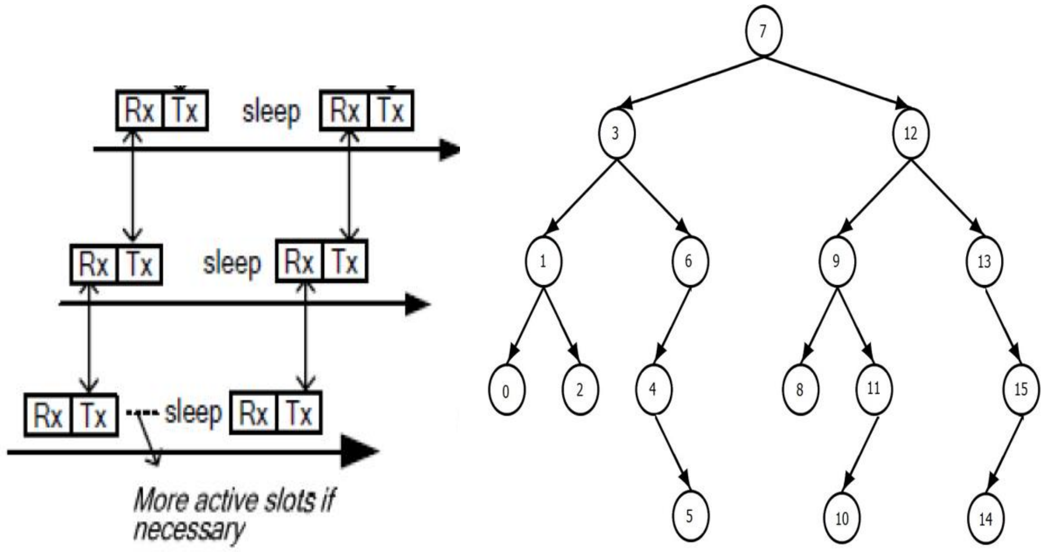

Figure 2.6: A data gathering tree and its DMAC implementation (Demirkol, 2006)

The advantage of DMAC is it achieves very good latency compared to other sleep/listen period assignment methods. Meanwhile, this protocol doesn't use collision avoidance. For this reason, when a considerable number of nodes on the same level try to send data to the same node, collisions will happen.

viii. DSMAC

Dynamic Sensor-MAC is an extension of SMAC which adds dynamic duty cycle and attempts to decrease the latency for delay-sensitive applications (Demirkol, 2006). In this protocol all nodes start with the same duty cycle, and when a node realizes that average one-hop latency is high, it decides to shorten its sleep time and announces it within SYNC period. As a consequence, after a sender node receives this signal, it checks its queue for packets destined to that receiver node and decides to double its duty cycle when its battery level is above a specified threshold. The duty cycle doubling is as shows in Figure 2.7.

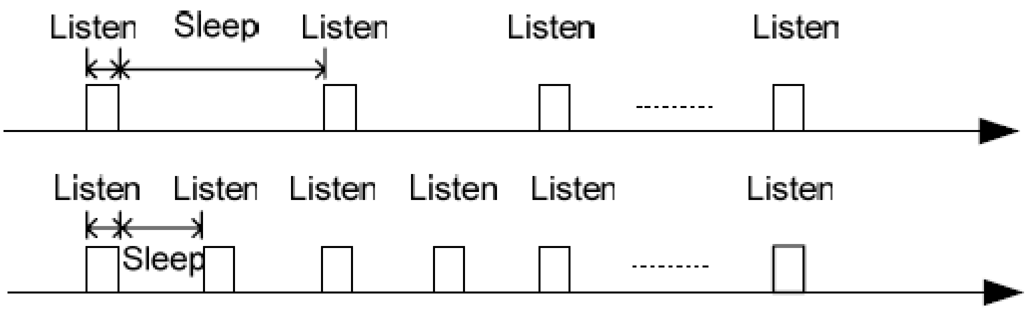

Figure 2.7: DSMAC duty cycle dubling (Demirkol, 2006)

i. CSMA

In Carrier Sense Multiple Access (CSMA), the nodes verify the absence of other traffic before transmitting on a shared transmission medium (Rom & Sidi, 1989). Two versions of CSMA exist which are non-persistent CSMA and p-persistent CSMA. In non-persistent CSMA, a backoff is performed before attempting to transmit if the sensed channel is busy, and the transmission is carried out immediately if the device senses no activity on the channel. In p-persistent CSMA, a node continues sensing the channel if it detects activity instead of delaying and checking again later. When the device senses no activity on the channel, it transmits a message with probability p and delays the transmission with probability 1 – p.

The benefit of CSMA/CA techniques in sensor networks depends on the traffic conditions, wireless channel characteristics, and network topology, so in some cases it may prove beneficial and in others an unnecessary overhead.

2.6 Routing in Wireless Sensor Networks

Routing is a process of determining a path between source and destination upon request of data transmission. In WSNs the network layer is mostly used to implement the routing of the incoming data. It is known that generally in multi-hop networks the source node cannot reach the sink directly. So, intermediate sensor nodes have to relay their packets. The implementation of routing tables gives the solution.

These contain the lists of node option for any given packet destination. Routing table is the task of the routing algorithm along with the help of the routing protocol for their construction and maintenance.

2.6.1. Routing Challenges and Design Issues

Depending on the application, different architectures and design goals/constraints have been considered for sensor networks. Since the performance of a routing protocol is closely related to the architectural model (Akyildiz, W et al.2002).

- Network dynamics: Most of the network architectures assume that sensor nodes are stationary, because there are very few setups that utilize mobile sensors. It is sometimes necessary to support the mobility of sinks or cluster-heads (gateways). Route stability becomes an important optimization factor, in addition to energy, bandwidth etc. As, routing messages from or to moving nodes is more challenging. So, the sensed event can be either dynamic or static depending on the application.

- Node deployment: It is application dependent and affects the performance of the routing protocol. The deployment is either deterministic or self-organizing. In deterministic situations, the sensors are manually placed and data is routed through pre-determined paths. Whereas in self-organizing systems, the sensor nodes are scattered randomly creating an infrastructure in an ad hoc manner. In later the position of the sink or the cluster-head is also crucial in terms of energy efficiency and performance. When the distribution of nodes is not uniform, optimal clustering becomes a pressing issue to enable energy efficient network operation.

- Energy considerations: During the creation of an infrastructure, the process of setting up the routes is greatly influenced by energy considerations. Since the transmission power of a wireless radio is proportional to distance squared or even higher order in the presence of obstacles, multi-hop routing will consume less energy than direct communication. However, multi-hop routing introduces significant overhead for topology management and medium access control. Direct routing would perform well enough if all the nodes were very close to the sink. Most of the time sensors are scattered randomly over an area of interest and multihop routing becomes unavoidable.

- Data delivery models: Data delivery model to the sink can be continuous, event driven, query-driven and hybrid, depending on the application of the sensor network. In the continuous delivery model, each sensor sends data periodically. In event driven and query-driven models, the transmission of data is triggered when an event occurs or the sink generates a query. Some networks apply a hybrid model using a combination of continuous, event-driven and query-driven data delivery. The routing protocol is highly influenced by the data delivery model, especially with regard to the minimization of energy consumption and route stability.

- Node capabilities: In a sensor network, different functionalities can be associated with the sensor nodes. Depending on the application a node can be dedicated to a particular special function such as relaying, sensing and aggregation since engaging the three functionalities at the same time on a node might quickly drain the energy of that node.

- Data aggregation/fusion: Similar packets from multiple nodes can be aggregated to reduce the transmission. For this sensor nodes might generate significant redundant data. Data aggregation is the combination of data from different sources by using functions such as suppression (eliminating duplicates), min, max and average.

2.6.2. Routing Objectives

Some sensor network applications only require the successful delivery of messages between a source and a destination. However, there are applications that need even more assurance. These are the real-time requirements of the message delivery, and in parallel, the maximization of network lifetime.

- Non-real time delivery: The assurance of message delivery is indispensable for all routing protocols. It means that the protocol should always find the route between the communicating nodes, if it really exists. This correctness property can be proven in a formal way, while the average-case performance can be evaluated by measuring the message delivery ratio.

- Real-time delivery: Some applications require that a message must be delivered within a specified time, otherwise the message becomes useless or its information content is decreasing after the time bound. Therefore, the main objective of these protocols is to completely control the network delay. The average-case performance of these protocols can be evaluated by measuring the message delivery ratio with time constraints.

- Network lifetime: This protocol objective is crucial for those networks, where the application must run on sensor nodes as long as possible. The protocols aiming this concern try to balance the energy consumption equally among nodes considering their residual energy levels. However, the metric used to determine the network lifetime is also application dependent. Most protocols assume that every node is equally important and they use the time until the first node dies as a metric, or the average energy consumption of the nodes as another metric. If nodes are not equally important, then the time until the last or high-priority nodes die can be a reasonable metric.

2.7Classification of wireless sensor networks

WSN Routing Protocols can be classified in four ways, according to the way of routing paths are established, according to the network structure, according to the protocol operation and according to the initiator of communications. Fig.2.8 shows the classification of WSN routing protocols.

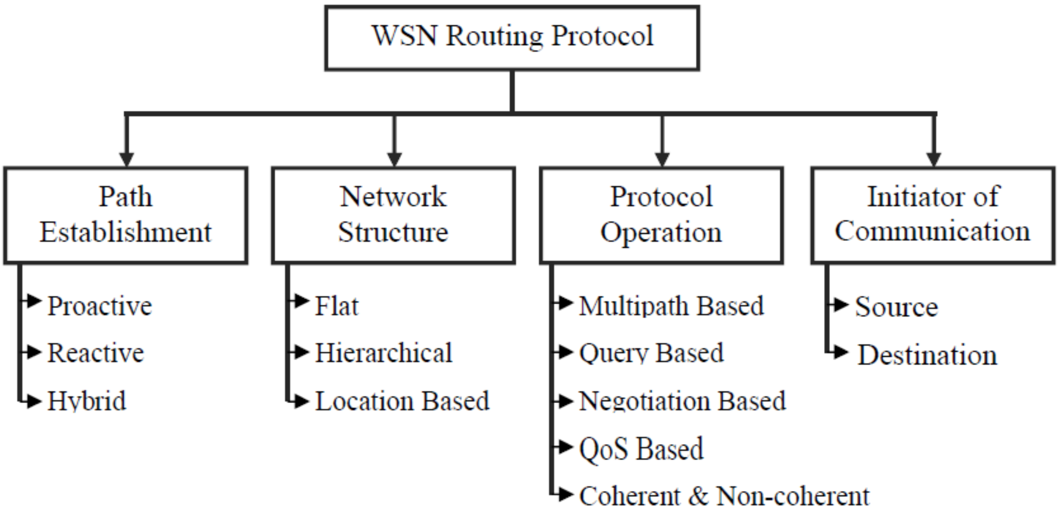

Figure 2.8: Classification of Routing Protocols in Wireless Sensor Network.

2.7.1 Path establishment

A Wireless Sensor Network can be classified based on their mode of functioning and the type of target application, Routing paths can be established in one of three ways, namely proactive, reactive or hybrid.

2.7.1.1 Proactive network

The nodes in this type of network periodically switch on their sensors and transmitters, sense the environment and transmit the data to the interest. This sort of network is suitable for application requiring periodic data monitoring. Some known instances of this kind are the LEACH protocol (Heinzelman et al., 2000) and some improvement of LEACH protocol (Xiangning&Yulin, 2007) (Loscri et al., 2005) (Yassein et al., 2009).

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