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AN APPROACH TOWARDS DISTRIBUTED QUALITY MONITORING OF DRINKING WATER IN THE RESERVOIRS

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Abstract: In this paper, we propose a fresh water environmental monitoring system based on wireless sensor networks which is suitable for the complex and large-scale water environment monitoring for drip irrigation. It is essential to track the water quality of water reservoir and lakes because any abnormal chemical components or pollutants can possibly cause health problems. Chemical Water Sensors may be utilized for such long-term monitoring purpose. We propose a scalable, low-energy, delay-tolerant Water-quality monitoring sensor network (WATER) version, which has essential differences from terrestrial radio sensor networks because of its highly variable, long propagation delay and mobility nature. We suggest a low-power data observation node based on ZigBee wireless technology; also GSM modem based tools and create software and its hardware. Different water quality detectors can be installed to meet the real-time monitoring for a broad assortment of water environment parameters.

Keywords: Water Quality; Sensor; Wireless Sensor Network; Zigbee Wireless Technology; Water Environment Monitoring System; Data Monitoring Nodes

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INTRODUCTION

Water surroundings, consisted of underground water environment and outside water environment, can be differentiated to water bodies like: lake, lake, reservoir, ocean, swamp, spring and glacier and shallow / deep underground oceans. Once damage or a change of water surroundings is witnessed in this complicated, change of other elements happens. In this way, as one of the procedures for water resource management and water pollution management, water environment monitoring, is found more crucial and more.

At present there are primarily four ways of water environment observation (see TABLE 1) and each has its own advantages and disadvantages [1].

TABLE 1. THE PRESENT METHODS OF WATER ENVIRONMENT MONITORING

Method	Advantages	Disadvantages
Artificial Sampling; Lab Analysis	*Many parameters for monitoring*	*Incapable in remote and real-time monitoring; Cost much labor and time*
Automatic Monitoring System of Water Environment (composed of monitoring center and several sub-station)	*Capable of automatic and successive monitoring; prompt; reliable in data transferring; less influenced by surrounding environment*	*dispose cables and set up sub-stations in advance; easily damage the ecological environment; A limited monitoring water area; costly to establish such a system*
Sensing Monitoring	*Less influence to environment; suitable for the quick monitoring on a large water area*	*Low accuracy; Costly; Difficult technology; demanding in data source; hard in real-time monitoring*
Organism Monitoring	*Cheap and directly visual result*	*Low accuracy; time-consumptive;*

Comparing with the current water detecting methods, building a tracking method based on the WSNs (wireless sensor networks) would present us with advantages as: low cost; advantage in tracking arrangement; varieties of parameters for collection; high detective accuracy and higher accountability of the monitoring system, etc.. WSNs (Wireless Sensor Networks) is a Ad-Hoc system composed of a fantastic number of tiny detection nodes, which are capable of detection, computing and communication, yet of low price and very low power consumption [7].

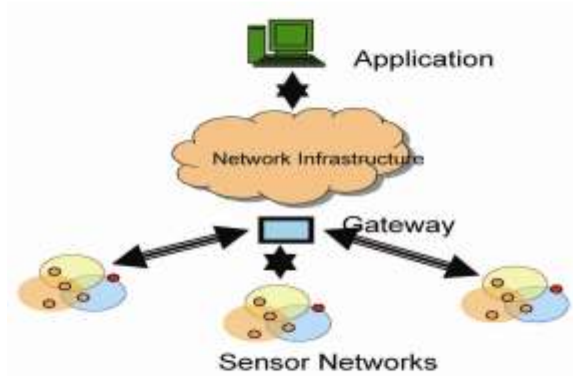


Fig-1. Wireless sensor network configuration

Monitoring system of water surroundings predicated on WSNs, as exemplified in Figure 1, could be separated into three parts: Data Monitoring nodes, Data Base Station and Remote Monitoring Center from the water area being detected. A great number of data monitoring nodes, dispersed in water region to be detected, dynamically constitute to a tracking network, in which, each node can not only collect parameters like pH value, amount of dissolved oxygen, electricity conductivity rate and temperature, but also capable of working linearization, temperature compensation, data packaging and memorizing all of the parameter collected, and route them to information base channel; data from monitoring nodes is to be transferred to remote monitoring centre by base station via GPRS network; the monitoring centre analyzes and processes the parameters of water quality, gives an alarm at the emergencies like water pollution, along with the abrupt reversal of water quality, also provides supports on the conclusion in avoidance and prevention of water contamination [5]. Attributes are presented by the whole water environment tracking system as large capacity of network disposition, very low power consumption, low cost, and impact on the surroundings.

II. LITERATURE REVIEW

Fei Hu Steve Wilson, Department of Computer Engineering, RIT, Rochester, New York USA; Yang Xiao Department of Computer Science, University of Alabama, USA Paper "Correlation-based Security in Time Synchronization of Sensor Networks", "they have reported their research results on constructing a secure, delay-tolerant Time Synchronization mechanism at the Water-quality monitoring sensor system (WATER) platform, that has crucial differences from terrestrial radio detector networks due to its highly variable, long propagation delay and freedom nature. From the vertical management, our lightweight time synchronization mechanism can achieve satisfactory timestamp precision. To make the time synchronization protocol withstand cyber-attacks, they have suggested a correlation-based security model to detect outlier timestamp information and identify nodes generating attacks.

Experiments have been conducted to validate the efficacy of their security approaches. There are still many difficult issues to be addressed, like the horizontal synchronization issue, which differs from vertical synchronization where we could use tree topology and hierarchical routing strategy. Nazleeni Samiha Haron, Mohd Khuzaimi B Mahamad, Izzatdin Abdul Aziz, Mazlina Mehat, Computer and Information Science Department, Universiti Teknologi, PETRONAS; Bandar Seri Iskandar, 31750 Tronoh, Perak Darul Ridzuan; in their newspaper "A System Architecture for Water Quality Monitoring System Using Wired Sensors", they propose a system architecture to get proactive water quality monitoring system. It's thought that by having such system jobs of tracking could be removed. The structure is consists of data acquisition; four elements, data telemetry, data processing and output. Three parameters used and will be tracked to evaluate temperature the water quality namely, pH, and dissolved oxygen. Fuzzy logic meanwhile is used to evaluate the data collected's fuzziness. The project could use Mamdani design of inference to produce the decision over water quality level of the pond. Additional work involves developing the prototype of this machine and analyzing the system in aqua farm for more accurate results.

Institute, Xia Hong-bo of Information and Control Hangzhou Dianzi University Jiang Peng, Institute Of Information and Control Hangzhou Dianzi University Wu Kai-hua, Institute For Biomedical Engineering and Instrumentation Hangzhou Dianzi University, Hangzhou, China; in their paper, "Layout of Water Environment Data Tracking Node Based On ZigBee Technology", they have designed the information monitoring node Based on ZigBee wireless low-power and technology MSP430 chip. This information Node was used within the water environment of an artificial lake Monitoring, and has achieved success in the water temperature and pH distant online auto-monitoring. Different water quality sensors can be installed on the Node so as to meet the real-time tracking for a wide array of water environment parameters. This monitoring system has a extensive application prospects.

III. SYSTEM HARDWARE DESIGNING

a) Design of PH meter

The hydrogen ion concentration is referred to by pH or how acidic or basic as water is and pH is log[H+]. PH value range from 0-14; pH 7 is neutral, pH<7 is acidic, and pH>7 is basic. PH transmitter is LE-438 that the pH. A weak voltage signal, output by the detector, was conversed into the 4~20mA standard signal via the circuit of pH and temperature transmitter. The circuit of transmitter can be split into two parts: electrical degree and the sign magnifying circuit raising circuit. One liter circuit could magnify four times bigger of the voltage.

Considering that the first one is a two-way differential signal, it is still a two-way compression signal after being magnified (-1.5V~1.5V). The magnified signal must have its electrical level raised to 0 ~3.0V to simplify the AD sampling of the microprocessor. Temperature signal should just be emptied. The magnified and increased voltage signal should converse 0 ~3V voltage signal to 4~20mA standard signal via V/I extending circuit and output to AD module at MCU. Figure-2 shows the transmitter.

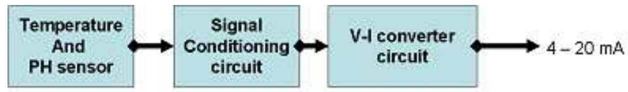


Fig-2. Single pH and temperature node design

b) Dissolved oxygen sensor

Dissolved oxygen describes the concentration of oxygen inside the water and it determined by the temperature of their water and the system's demand. Dissolved oxygen is used in chemical oxidation of mineral, respiration of aquatic organism, and decomposition of organic matter. As organisms from the water use dissolved oxygen, therefore it has a tendency to change. Dissolved oxygen is provided to direct diffusion of oxygen from the atmosphere, wave and wind action; water through method; and photosynthesis [3].

c) Temperature measurement

Water temperature Could be Quantified using Traditional RTD (Resistance Temperature Detector), thermistors, thermocouples. The temperature can be measured using the and these detectors Temperature could be converted to electrical (voltage or current) form.

d) Turbidity measurement

Turbidity is an expression of the optical property that causes light to be absorbed and scattered by particles and molecules rather than transmitted in straight lines through a water sample [2]. It's caused. Turbidity can produce health concerns because impurities provide protection for bacteria by reducing their exposure. Turbidity may also pose issues for apparatus in water, causing damage and, perhaps, final devastation. Several methods and systems can be found to calculate on a water sample, but the most exact is turbidimeter or that the nephelometer that uses an origin and grabs light and the light transmitted scattered. The ratio between these dimensions provides values which enable us to calculate turbidity from nephelometer turbidity units (NTUs).

Turbidimeter is essentially constituted a sample cell, by a couple of light emitters, and one or more light receivers [6]. Most light emitters are infrared LED and tungsten filament lamps. A photo detector will be chosen in line with the kind of light source: For tungsten-filament lamps, Photo-Multiplier Tubes (PMTs) are utilized, or photodiodes are used while the emitter is an LED [4]. This paper presents a new system which can be utilized in dimensions; this design benefit from using optical fibers as a path; therefore, several benefits are obtained.

1) Waterproof protection becomes unnecessary because no electrical parts are under water. A consequence is that we get a small and low-cost sensor.

2) The use of fibers allows us long-distance measurement without interference or attenuation risks. Therefore, this kind of system will be extremely interesting for remote measurement in a heavy Electro-Magnetic Interference (EMI) environment.

3) The overall design is valid for any configuration topology and for any light source and kind of detector. In the next sections, an optical-fiber turbidimeter design is presented, including block diagrams, design criteria, and experimental results.

Design Considerations of Turbidimeter

There are several turbidimeter topologies, but only three are approved by the Environmental Protection Agency (EPA) and the International Organization for Standardization [2]:
1) simple-beam design;
2) ratio-algorithm design;
3) four-modulated-beam design.

The simple-beam design is the most simple and less precise design. It does not have a good response with colored samples, and it is mainly used for low turbidity ranges. Results are more precise in the ratio-algorithm design, owing to the use of more detectors at different angles, which allows us partial cancellation of errors due to wavelength absorption in colored samples [7]. A four-beam turbidimeter is constructed of four different blocks: emission circuit, optical path (fibers and sample cell), light-reception circuit, and control section that are able to carry out calculations, visualization, and control. Figure-3 shows a first approximation to this design.

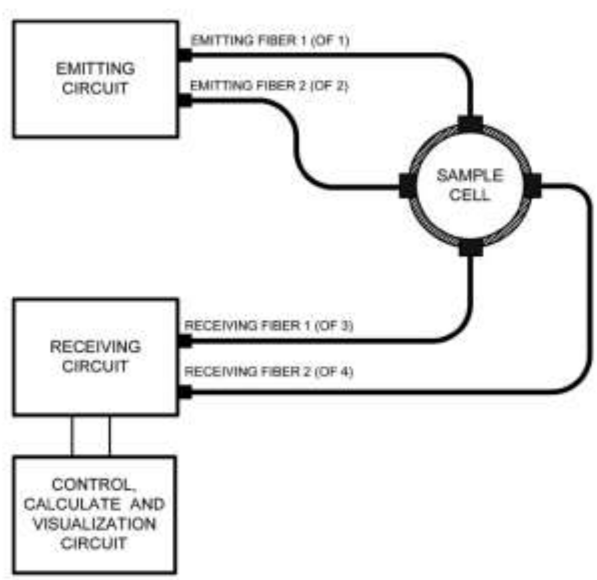


Fig-3. Basic block diagram of a four-beam turbidimeter.

Sensor Design and Operation

The analyzer's design was described in detail elsewhere and is summarized here. The machine comprises polyethylene bags for storing the reagent, calibration options and cleaner, a sample interface for collecting and filtering the water sample and a range of solenoid pumps for pumping the fluids throughout the microfluidic chip. The sample interface retains a polyethersulfone membrane filter with 0.45 µm pore dimensions, which prevents particulate matter from entering the microfluidic system. The microfluidic chip allows for the mixing of sample and the reagent. The chip also presents photodiode and some LED to get an measurement with the reacted sample. The analyzed sample is subsequently pumped to the waste storage. All the handling and analytical elements are controlled by a microcontroller that performs the data acquisition and stores the data in a flash memory unit [7]. A GSM (Global System for Mobile communications) modem is used to communicate the data via the SMS protocol to a notebook computer. The whole integrated system is shown in Fig. 4. The microcontroller used to restrain the machine is the MSP430F449 (Texas Instruments). This was selected during sleep and operational mode. A 2 megabyte SPI flash processor mounted on the PCB with the microcontroller allows for 16,384 data points to be logged. The solenoid pumps along with the power to the GSM modem are controlled through an array of field effect transistors (FETs).

Power is provided by a 12 V, 7Ah lead acid battery. A photodiode (S1227-33BR, Hamamatsu Photonics UK Limited, Hertfershire, UK) and a 370nm LED (NSHU550E, Nichia Corporation, Tokushima, Japan) are used for the absorbance dimension [9]. A transimpedance amplifier circuit based around a TLV2772 operational amplifier (Texas Instruments) is used to condition the signal from the photodiode. This circuit is built on another board close to the microfluidic processor restricting the sound. The entire system is enclosed within a robust and portable instance (1430 instance, Peli Products, Barcelona, Spain) which is water- and airtight when closed. The operation of this chip would be to combine the sterile sample or phosphate standard together with the reagent and to present the LED and photodiode spectrophotometer [8] with the resulting mixed solution. For this effect the processor contains a micro-cuvette along with a T-Mixer. To ensure mixing in a 1:1 ratio, channels leading from the inlets into the T-mixer are of equal length and location. This ensures that the resistance is equivalent for all stations. Given the answers to be combined are injected at pressure they will have flow rates that are equal when they will mix at a 1:1 ratio and meet at the T-Mixer.

Fig-4. The prototype phosphate analyzer system. (1) Electronics board. (2) GSM modem. (3) Microfluidic chip / detector assembly. The battery, storage bottles, and solenoid pumps are contained within the lower part of the case.

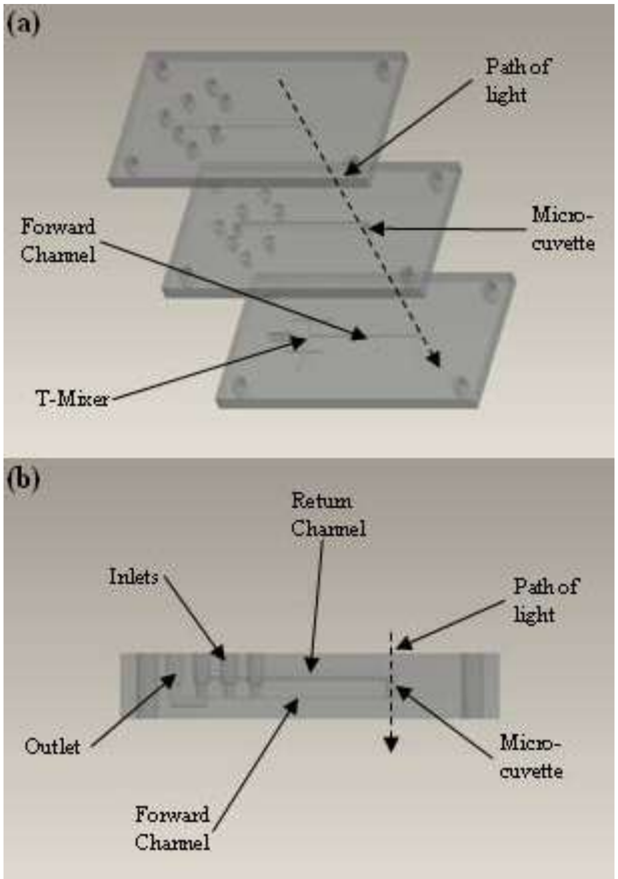


Fig-5. (a) Exploded view of the microfluidic chip. (b) Side view of fully assembled chip showing the micro-cuvette.

The microfluidic chip design is shown in Fig-5. The three layers were fabricated using a CNC micro-mill (CAT-3D-M6, DATRON, UK) from PMMA (poly methyl-methacrylate) sheets (Radionics, Ireland). The layers were then sonicated in distilled water to remove debris from the machining process. To assemble the chip the mating surfaces are irradiated with UV light at 185 and 254 nm. This process made the surface of the normally hydrophobic PMMA hydrophilic which allows them to be bonded below the glass transition temperature of PMMA. The layers were aligned and assembled using 2mm steel dowel pins placed in alignment holes in the corners. The assembled chip put under pressure using G-clamps and heated to 80° C for 2 hours. 0.8 mm inner diameter PEEK tubes are inserted into the inlet holes as interconnects.

Fig-6. The phosphate sensor in situ during the trial at Broad meadow Water, Co. Dublin, Ireland in September 2009. The sample inlet is visible below the water line.

Following a laboratory-based calibration procedure, the sensor was placed *in situ* at Broad meadow Water in Co. Dublin, Ireland on 25 September 2009. This is an estuarine water body which is known to have significantly elevated nutrient levels due to a combination of inputs from agricultural sources and wastewater treatment plant discharges. The sensor was located at a small islet in one of the estuary channels and held in place using a steel anchoring device. As this was a tidal location, the GSM modem antennae was located outside the box and elevated above the high-water mark to ensure constant network coverage, as the sensor enclosure itself was fully immersed at high tide. The sensor operated with hourly sample frequency, and data was transmitted by the GSM modem in SMS (Short Message Service) mode to a laboratory-based laptop computer at 5 hour intervals. For validation purposes, daily manual samples were collected as close as possible to the sensor's sample inlet, and timed to coincide with the sensor's sampling time. Samples were filtered immediately, and analyzed using a Hach-Lange DR890 portable colorimeter and the appropriate reagent pack (amino acid method for high range phosphate).

e) Communication protocol

The proposed communication protocol used in this project is a medium access control protocol based protocol (WiseMAC). WiseMAC is a medium access control protocol [Fig-7] designed for the WiseNETTM wireless sensor network. It is based on CSMA and uses the preamble sampling technique to minimize the power consumed when listening to an idle medium. A unique feature of this protocol is to exploit the knowledge of the sampling schedule of its direct neighbors in order to use a wake-up preamble of minimized size. This scheme allows not only to reduce the transmit and the receive power consumption, but also brings a drastic reduction of the energy wasted due to overhearing. Back-off and medium reservation schemes have been selected to provide fairness and collision avoidance. WiseMAC requires no set-up signaling, no network-wide time synchronization and is adaptive to the traffic load. It provides ultra-low average power consumption in low traffic conditions and high energy efficiency in high traffic conditions.

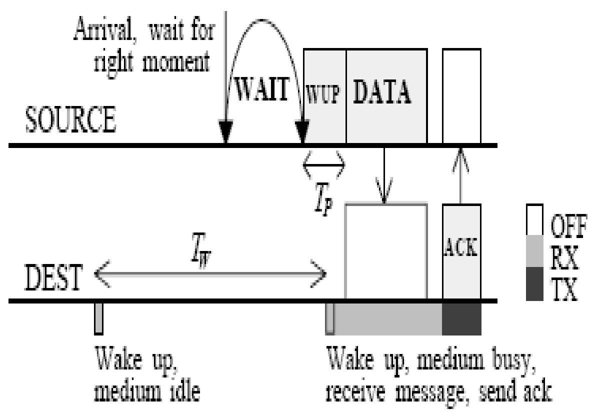


Fig-7. Simple WiseMAC protocol architecture

f) Final system design:

The final system contains a pH sensor, temperature sensor and dissolved oxygen sensor connected to corresponding signal conditioning circuits for signal processing and analysis of data. A transmitter is used to transmit the data to the central location for digital display and proper analysis.

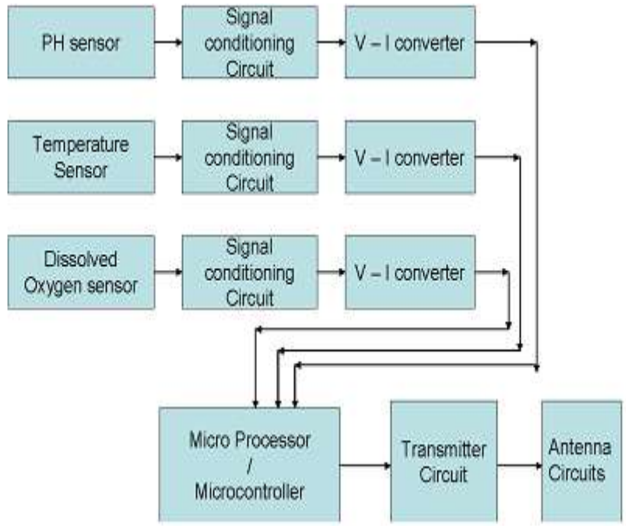
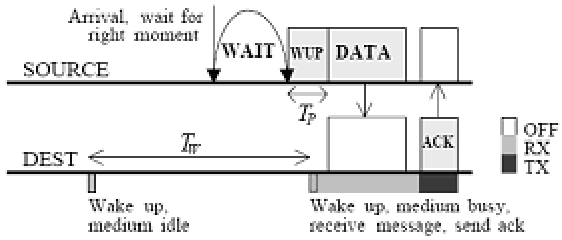


Fig-8. Simple sensor node with different sensors mounted on it.

Communication link and protocol design WiseMAC uses the preamble sampling technique to minimize the energy wasted during idle listening. Preamble sampling consists in regularly sampling the medium to check for activity. By sampling the medium, it is meant listening to the radio channel for a short duration, e.g. the duration of a modulation symbol. In a network, all nodes sample the medium with the same constant period *TW*, independently of the actual traffic. Their relative sampling schedule offsets are independent. If the medium is found busy, the receiver continues to listen until a data packet is received or until the medium becomes idle again. At the transmitter, a wake-up preamble is transmitted in front of every message to ensure that the receiver will be awake when the data portion of the message will arrive. The wake-up preamble introduces power consumption overhead both in transmission and in reception. To minimize this overhead, sensor nodes learn the offset between the sampling schedule of their direct neighbors and their own one. Knowing the sampling schedule of the destination, sensor nodes send messages just at the right time with a wake-up preamble of minimized length *TP* (see Fig-8). As nodes have independent sampling schedule offsets, this scheme naturally mitigates overhearing, since such short transmissions are likely to fall in between sampling instants of potential over- hearers. Every node keeps an up-to-date table with the sampling schedule offset of its direct neighbors. The sampling schedule offset information is gained through the inclusion in every acknowledgement packet of the remaining duration until the next scheduled preamble sampling. Because the clocks running on the sender and the destination can be inaccurate, a drift will accumulate in between two transmissions. To compensate this drift, it can be shown that the wakeup preamble must have a duration of $4\vartheta L$, if both quartz have an accuracy within $\pm\vartheta$ parts per million. L is the time elapsed since the last acknowledgement message was received from the destination. WiseMAC is hence adaptive to the traffic load, in the sense that the higher the traffic (the smaller L), the smaller the wake-up overhead ($4\vartheta L$). With this scheme, it is not necessary to regularly exchange data frames to keep the synchronization. If the interval between two communications is so large that $4\vartheta L > TW$, a wake-up preamble of length *TW* will be used. This also applies to the first communication between two nodes. In those cases where the wake-up preamble is longer than the data frame, it is composed of a repetition of the data frame. This permits to reduce the frame error rate, mitigate overhearing and detect interferences. To mitigate collisions, WiseMAC uses non-persistent carrier sensing, with a back-off chosen as a random integer multiplied by the turn-around time of the transceiver. To prevent collisions between two or more nodes that want to send a data frame to the same relay and at the same target sampling instant, a medium reservation preamble of randomized duration is added in front of the wake-up preamble. After the wake-up preamble, the WiseMAC data frame includes a bit synchronization preamble and a start frame delimiter (see Fig. 2). Collisions caused by the hidden node effect can represent an important source of energy waste through the required retransmissions. The hidden node effect is mitigated by extending the carrier sense range beyond the interference range, at the cost of the capacity. The receive threshold has been chosen well above the noise threshold to mitigate useless wake-ups caused by interferences or weak signals. The receiver is hence waken up only when this is really worth it. Here, the lower power consumption is traded against a potential transmission range extension. The efficient transport of data bursts is made possible through the use of the 'more' bit in the header of data packets, indicating to the receiver to continue to listen for the following packet.

Evaluation of WiseMAC

The WiseMAC protocol was simulated on the GloMoSim platform. The radio layer of the simulation environment has been modeled to reflect the temporal behavior of the WiseNET transceiver: a setup delay of 800 μs (between off state and ready for receive) and a turn-around delay of 400 μs (between the receive and transmit states). Simulations were run for a 9x9 lattice multi-hop network. The node density was chosen to be of 9 nodes within a circle of range radius, such as to provide a well-connected topology in a random plane ad-hoc network of equal density. Traffic is generated following a Poisson process by the 9 nodes on the left of the lattice, and carried in a multi-hop fashion towards the right. MPDU frames have a length of 64 bytes. The channel raw bit rate is of 25 kbps. The wake-up period was chosen to be TW = 200 ms, such that the power consumed by the preamble sampling activity is within the given power budget but not negligible when compared to the battery leakage power. The statistics collected on a central forwarding node have shown that, when using the WiseNET transceiver, the average power consumption accounts to 25 μW when a message is forwarded in average every 100 seconds. With a single alkaline battery of capacity C=2.6 Ah and constant power leakage of 27 μW, this translates in more than 5 years lifetime.



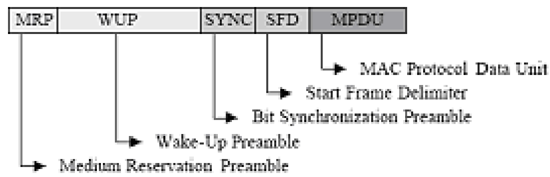


Fig-8. WiseMAC protocol packet format

In higher traffic conditions (inter-arrivals between 100 and 5 seconds), the average power consumption of WiseMAC grows up to 200 μW, but the energy efficiency reaches over 75%. Here, we define energy efficiency as the ratio between the energy consumed by an ideal protocol to forward a packet (without any wake-up, idle listening, overhearing or collision overhead) divided by the energy consumed by WiseMAC to forward the same payload. The average hop latency was measured between 140 and 240 ms, depending on the traffic conditions.

CONCLUSION

Wireless sensor system established water quality sensor nodes play a role and wellbeing health difficulties. These nodes could be deployed in a diverse assortment of water environment for the water quality detection procedure. By implementing energy efficient sensor network the node life time could be raised to 3-4 years. WiseMAC is a CSMA established protocol employing the preamble sampling method to decrease the expense of listening. This protocol harnesses the knowledge of its neighbors' schedule to lessen the period of the preamble. It's thereby flexible to the traffic loading, supplying energy efficiency in traffic conditions along with power consumption in traffic conditions.

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