INTERNET OF THINGS BASED WIRELESS SENSOR NETWORK SYSTEM FOR WATER QUALITY MONITORING

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INTERNET OF THINGS BASED WIRELESS SENSOR NETWORK SYSTEM FOR WATER QUALITY MONITORING

By

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In the Name of Allah, the Most Beneficent and the Most Merciful. All praise is due to Allah, Lord of the worlds. The Entirely Merciful, the Especially Merciful, sovereign of the Day of Recompense. It is You we worship and You we ask for help. Guide us to the straight path. The path of those upon whom You have bestowed favor, not of those who have evoked Your anger or of those who are astray. Peace and blessings be upon Prophet Muhammad and his family. Peace be upon him, The Sealed of the Prophet and there will be no more Prophet after him.

Science and religion could not be separated from one another. Science research would prove the truth of religion that is so true and pure. The truth of the Qur'an would be proven by the scientific investigation that can be accepted by the human mind. God created this universe to show His infinite power so that we as humans that has nothing in hands would always thought and humbled Himself.

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LIST OF ABBREVIATIONS

AC	Alternate Current
ADC	Analog-to-Digital Converter
AES	Advance Encryption Standard
AIDL	Auto-ID Lab
AM	Ante Meridiem
AP	Access Point
API	Advance Programming Interface
APK	Android Package Kit
ARM	Acorn RISC Machine
ASCII	American Standard Code for Information Interchange
AT	Application Transparent
AVR	Alf and Vegard's RISC
BNC	Bayonet Neill-Concelman
BOD	Biochemical Oxygen Demand
BPS	Bit Per Second
C	Celsius
CD	Compact Disc
COD	Chemical Oxygen Demand
COM	Communications
CPU	Central Processing Unit
CSS	Cascading Style Sheet
CSW	Cloud Storage/Webserver
CWE	Continuous Wave Emitter
DC	Direct Current

DC-DC	Direct Current-to-Direct Current
DLM	Digital Lifestyles Malaysia
DO	Dissolved Oxygen
DOE	Department of Environment
DSSS	Direct Sequence Spread Spectrum
E	East
EC	Electrical Conductivity
EEPROM	Electrically Erasable Programmable Read Only Memory
EIG	Embedded Internet Gateway
EIRP	Effective Isotropic Radiated Power
EM	Electromagnetic
EMF	Electromagnetic Field
EMI	Electromagnetic Interference
EU	European Union
F	Fahrenheit
FHSS	Frequency Hopping Spread Spectrum
FPGA	Field-Programmable Gate Array
FR	Flame Retardant
FTDI	Future Technology Devices International
GB	Gigabyte
GND	Grounding
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile
GUI	Graphical User Interface

HAWB	House Air Way Bill
HDD	Hard Disc Drive
HF	High Frequency
HTML	Hyper Text Markup Language
IC	Integrated Circuit
ICSP	In-Circuit Serial Programming
ID	Identification
IDE	Interface Development Environment
IEEE	Institute of Electrical and Electronics Engineers
IEM	Institution of Engineers Malaysia
IMWQS	Interim Marine Water Quality Standards
I	Current
IIC	Integrated Interface Circuit
I/O	Input/Output
IOS	IPhone Operating System
IOT	Internet of Things
IP	Internet Protocol
IPV4	Internet Protocol Version 4
IPV6	Internet Protocol Version 6
IR	Infra-Red
ISM	Industrial, Scientific, & Medical radio frequency band
ISP	Internet Service Provider
IT	Information Technology
ITU	International Telecommunication Union
JTAG	Joint Test Action Group

KB	Kilobyte
LAN	Local Area Network
LED	Light Emitting Diode
LF	Low Frequency
LI-ION	Lithium Ion
LOS	Line-of-Sight
LTE	Long Term Evolution
MAC	Media Access Control
M2M	Machine-to-Machine
MB	Megabyte
MCMC	Malaysian Communications and Multimedia Commission
MEN	Monitoring End Node
MIPS	Million Instructions Per Second
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
N	North
NC	Normally Close
NIMH	Nickel Metal Hydride
NIZN	Nickel Zinc
NLOS	Non-Line-of-Sight
NO	Normally Open
NPM	Nightly Panic Munchies
NH3N	Ammoniacal Nitrogen
OS	Operating System
OSI	Open System Interconnection
P	Power

PAA-IOA	Poly Acrylic Acid co – Iso Octyl Acrylate
PAN	Private Area Network
PC	Personal Computer
PCB	Printed Circuit Board
PH	Potential Hydrogen
PHP	PHP: Hypertext Preprocessor
PIC	peripheral Interface Controller
PL	Power Level
PM	Post Meridiem
POC	Proof of Concept
PPM	Part Per Million
PRE	Pseudo-Reference Electrode
PWM	Pulse Width Modulation
RAM	Random Access Memory
RCMS	RFID-based Cargo Management System
RF	Radio Frequency
RFID	Radio Frequency Identification
RJ	Registered Jack
RPSMA	Reverse Polarity Sub-Miniature Version A
RSSI	Receive Signal Strength Indication
RST	Reset
RTC	Real-Time Clock
RX	Receive
SD	Secure Digital
SAAS	Software As A Service

PAAS	Platform As A Service
IAAS	Infrastructure As A Service
SKMM	Suruhanjaya Komunikasi Dan Multimedia Malaysia
SMD	Surface Mount Device
SPI	Serial Peripheral Interface
SQL	Structured Query Language
SRAM	Static Random Access Memory
SRD	Short Range Device
SSL	Secure Sockets Layer
TCP	Transmission Control Protocol
TLS	Transport Layer Security
TSS	Total Suspended Solid
TX	Transmit
UART	Universal Asynchronous Receiver/Transmitter
UDP	User Datagram Protocol
UHF	Ultra-High Frequency
USB	Universal Serial Bus
USM	Universiti Sains Malaysia
V	Voltage
VCC	Common Collector Voltage
VDC	Direct Current Voltage
WE	Working Electrode
WEP	Wireless Encryption Protocol
WI-FI	Wireless Fidelity
WLAN	Wireless Local Area Network

WORM	Write One Read Many
WPA	Wi-Fi Protected Access
WQI	Water Quality Index
WQM	Water Quality Monitoring
WSN	Wireless Sensor Network
WWW	World Wide Web
3G	Third Generation

SISTEM RANGKAIAN PENDERIA WAYARLES BERASASKAN INTERNET KEBENDAAN BAGI PEMANTAUAN KUALITI AIR

ABSTRAK

Secara umum, sungai adalah sumber utama air untuk makhluk hidup. Kualiti air sungai menjejaskan kesihatan kita secara langsung yang boleh membahayakan jika kita menggunakan air tercemar. Terima kasih kepada kemajuan teknologi dalam pemantauan kualiti air semasa (WQM) untuk penggunaan air yang selamat. Pada dasarnya, WQM di tapak dan WQM yang berterusan sedang dilaksanakan secara meluas di Malaysia. Kaedah di tapak menyediakan mobiliti yang tinggi, kos operasi yang rendah dan kebarangkalian masalah kecurian atau kerosakan peralatan rendah kerana tiada pemasangan tetap di lokasi WQM diperlukan. Walau bagaimanapun, ia terdedah kepada kebarangkalian ralat manusia yang tinggi disebabkan operasi manual dan penyelesaian data masa nyata yang tidak konsisten. Sementara itu, WQM berterusan atau juga dikenali sebagai WQM berasaskan stesen automatik menyediakan penyelesaian data masa nyata yang konsisten tanpa kesilapan manusia semasa proses WQM. Tetapi kelemahannya adalah mobiliti yang rendah, kebarangkalian masalah kecurian yang tinggi disebabkan pemasangan peralatan tetap dan melibatkan kos operasi yang tinggi. Oleh itu, objektif kajian ini adalah untuk merekabentuk sistem WQM hibrid yang boleh memperbaiki isu-isu semasa kedua-dua kaedah WQM menerusi pembenaman pelbagai teknologi wayarles.

Sistem Pengenalan Frekuensi Radio (RFID), rangkaian penderia wayarles (WSN) dan jalur lebar internet disatukan menjadi satu platform ekosistem internet kebendaan (IoT) iaitu dinamakan IoT untuk sistem pemantauan kualiti air (IoT-WQM) adalah dikaji. Sistem IoT-WQM yang dicadangkan menyediakan pemantauan masa nyata terhadap tahap pH dan suhu persekitaran dan dipertingkatkan dengan sistem

pemicu amaran mudah alih melalui peranti mudah alih. Untuk mencapai matlamat kajian ini, satu prototaip sistem yang dicadangkan direka dan dibangunkan berdasarkan kajian literasi. Kemudian ia dianalisis oleh beberapa siri eksperimen untuk menyiasat prestasi dan sifatnya. Ini termasuk pengesahan frekuensi, analisis tenaga, analisis pengesanan anti-perlanggaran, analisis ujian jangkauan WSN, penghantaran dan lengah rangkaian

Berdasarkan analisis yang dijalankan, perbezaan peratusan purata bagi pengukuran pH semasa keadaan cuaca basah adalah 0.31% untuk sistem IQT-WQM dan 0.28% untuk sistem RFID kendiri. Sementara itu, perbezaan peratusan purata semasa keadaan cuaca kering untuk IoT-WQM dan sistem RFID kendiri masing-masing adalah 0.36% dan 0.33%. Analisis pengesanan anti-perlanggaran menunjukkan kecekapan menerima 100% paket maklumat yang dihantar dengan tag IoT-WQM. Hasil ujian jangkauan luaran maksimum dalam persekitaran lompatan tunggal LoS sistem IoT-WQM berdasarkan ekstrapolasi adalah 100% sama dengan spesifikasi XBee Pro iaitu 6.5 km. Manakala bagi lompatan pelbagai di dalam persekitaran NLoS, bacaan maksimum RSSI mencapai -85 dBm pada jarak 1000 m. Purata penghantaran sistem IoT-WQM adalah 0.23% sedikit lebih tinggi daripada sistem RFID kendiri untuk kedua-dua mod yang disulitkan dan tidak disulitkan. Sementara itu, purata lengah sistem IoT-WQM sedikit lebih tinggi daripada sistem RFID kendiri untuk kedua-dua mod yang disulitkan dan tidak disulitkan masing-masing sebanyak 0.12% dan 0.45%.

INTERNET OF THINGS BASED WIRELESS SENSOR NETWORK SYSTEM FOR WATER QUALITY MONITORING

ABSTRACT

Generally, rivers are the main resource of water for living thing. The river's water quality affects our health directly which can be harmful if we consume contaminated water. Thanks to the advancement of technology in current water quality monitoring (WQM) for safe water consuming. Basically, on-site WQM and continuous WQM are being extensively deployed in Malaysia. The on-site method provide high mobility, low operation cost and low probability of theft problem or equipment damage as there is no fixed installation at WQM spot is required. However it vulnerable to high probability of human error due to manual operation and non-consistent real-time data solution. Meanwhile, the continuous WQM or also known as automatic station-based WQM provides consistent real-time data solution with no human error during WQM process. But its disadvantages are low mobility, high probability of theft problem due to fixed equipment installation and involve high operation cost. Therefore, the objective of this study is to design a hybrid WQM system which can improve the current issues of both WQM methods through multiple wireless technologies embedment.

The Radio Frequency Identification (RFID) system, WSN and internet bandwidth are consolidated into one platform of Internet of Thing (IoT) ecosystem namely IoT for water quality monitoring (IoT-WQM) system is studied. The proposed IoT-WQM system provides real-time monitoring on pH level and ambient temperature and enhanced with mobile alert triggering system through mobile device. To achieve the objective of this study, a prototype of proposed system are designed and developed based on literature reviews. Then it was analyzed by several series of experiment to

investigate its performance and characteristic. This includes frequency verification, energy analysis, anti-collision detection analysis, WSN range test analysis, throughput and network latency.

Based on conducted analyses, the average percentage difference for pH measurement during wet weather condition are 0.31 % for IoT-WQM system and 0.28 % for standalone RFID system. While, the average percentage difference during dry weather condition for the IoT-WQM and standalone RFID systems are 0.36 % and 0.33 % respectively. The analysis of anti-collision detection shows a 100 % receiving efficiency of the transmitted information packet by transmitting IoT-WQM tags. The maximum outdoor range test result in LoS environment of IoT-WQM system based on extrapolation is 100 % identical with the XBee Pro specification which is 6.5 km. Meanwhile, the maximum reading of average RSSI value for multihop NLoS communication is -85 dBm at 1000 m distance. The average throughput of IoT-WQM system is 0.23% slightly higher than standalone RFID system for both encrypted and unencrypted modes. Meanwhile, the average latency of IoT-WQM system is slightly higher than standalone RFID system for both encrypted and unencrypted mode which are 0.12 % and 0.45 % respectively.