Cloud-based Remote Environmental Monitoring System with Distributed WSN Weather Stations

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***Abstract*—Multiple weather stations and Wireless Sensor Network (WSN) system deployed throughout the state of Perlis to monitor weather and environmental conditions. Weather data from sensor nodes hops through WSN nodes towards base station attached to embedded computer system. These data accessible by eKoView, web-based monitoring application provided. However, current system limits monitoring to local area connected by WSN nodes. Since, weather stations operate at multiple geographical areas beyond nodes range, an online cloud server bridge these gaps to collect sensor data from local base stations to centralized database. Online users can access website with WSN base stations marked on Google Map and dynamically plot graph of historical weather data.**

Keywords—Wireless Sensor Network (WSN); environmental monitoring; weather station; cloud server

I. Introduction

State of Perlis enjoys tropical climate with uniform temperature, high humidity and abundant rainfall [1]. Weather often varies greatly from place to place within few kilometers apart. Satellite-based weather observations are expensive and inaccurate in predicting weather for these local areas. Hence, Mesoscale and Microscale Meteorology technique were applied for local weather system prediction and planning [2]. Previous research found that distributed ground weather station outperform satellite-based observations in measuring rainfall and soil conditions at different depth which are greatly emphasized in agriculture [3].

Wireless Sensor Network (WSN) technology proved to be an interesting research tool nowadays as various potential applications [4] proposed by research in various areas such as weather monitoring [5,6], precision agriculture [7,8], smart building, healthcare [9], military and others [10,11]. Extensive research on architectures, protocols, applications, and management for wireless sensor network has been done by previous researchers [12]. Arjun et al. [5] worked on enhanced architecture for integrating cloud with wireless sensor networks. The author continued by analyzing weather data to alert SaaS users during weather disasters.

As for our case, deployment of WSN throughout a large monitoring area to relay data from distributed weather stations to single base station are expensive and ineffective due to its distance from other weather stations.

A simple and cost effective approach were devised to link distributed WSN base stations to an online cloud server and provide online web service for users to access the weather data.

This paper discusses the system architecture and implementation of cloud-based remote environmental monitoring system with distributed weather stations. The proposed cloud-based system provide increased data collection capacity from distributed WSN base stations, replication of data to reliable database and allow online user access to weather data. An embedded computer system based server developed to collect data from wirelessly connected weather stations and WSN nodes as well as periodically push latest sensor data to the central cloud server.

II. Implementation

The proposed system consist of weather stations deployed at 6 areas across the state of Perlis connected to local base station at each location via WSN nodes. These local base stations collect and store data collected from weather station, WSN nodes with additional sensors and network health for diagnostic purposes before pushing all the data to a central cloud server as shown in Fig. 1. Existing wireless sensor network deployment landscape consist of three distinct software tiers, mote tier, server tier and client tier [13,15]. An additional cloud tier placed between server tier and client tier as in Fig. 1, proposed to link the distributed base stations or weather station.

A. Mote Tier – Distributed Weather Stations

In order to sense the environment for weather parameters, Memsic eKo weather station [14] were deployed at 6 areas throughout the state of Perlis, namely at the University Main Campus at Pauh Putra, Research Center at Jejawi, UniCity Campus at Sungai Chuchuh, Forest Research Institute at Mata Ayer, Swiftlet Farm at Arau and Prawn Farm at Kerpan. The weather station integrated with anemometer, rain collector, temperature, humidity, barometric pressure and solar radiation sensor with optional soil moisture sensor for comprehensive agricultural and environmental sensing in one package for simple setup [14].

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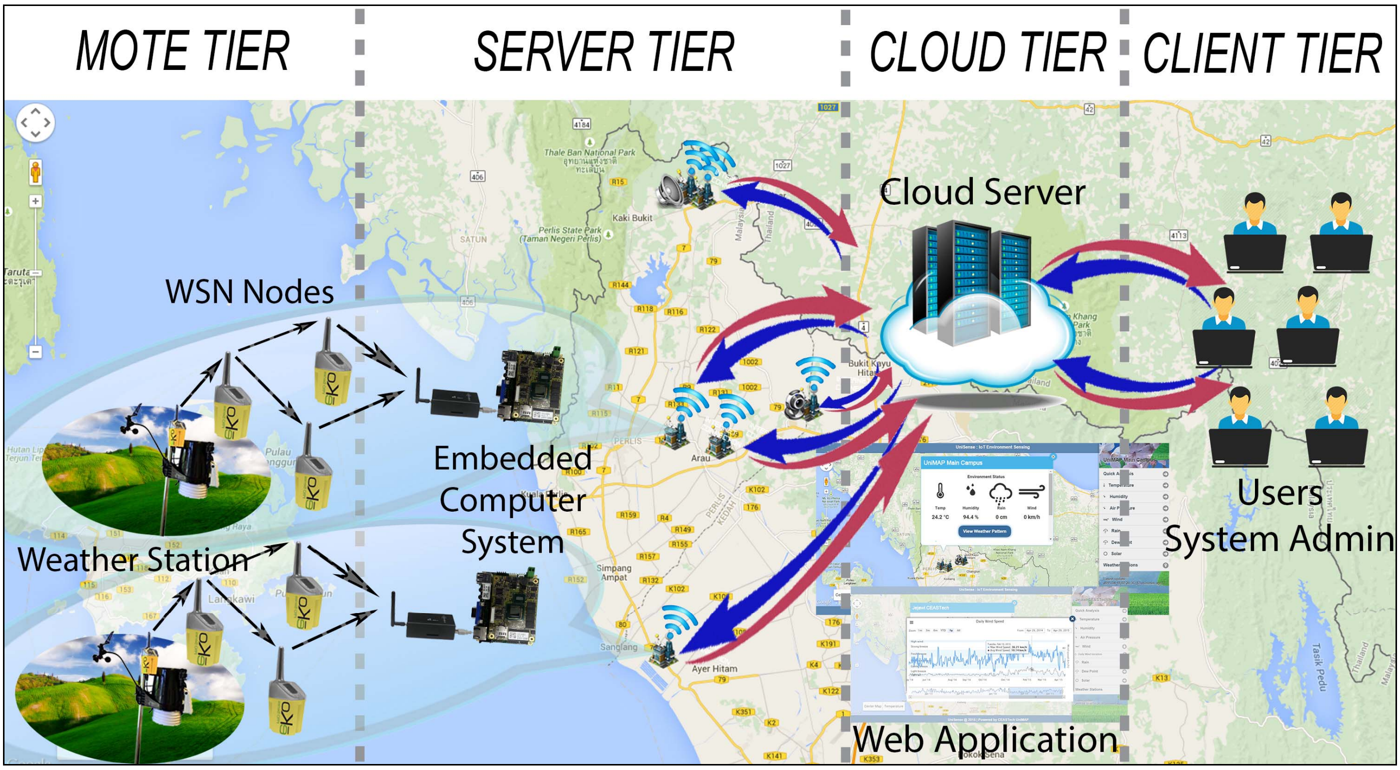

Fig. 1. System architecture for WSN-Cloud integration

The weather station with plug-and-play capabilities rely on solar powered node to form mesh wireless network for relaying weather data to base station every 15 minutes. XMesh is a mesh networking protocol for wireless network developed by Memsic. Nodes in XMesh network able to wirelessly communicate to other nodes and hop radio data to a base station or PC, effectively extends radio communication range and minimize power required to transmit data [15]. Node battery life can last for many years as it stays in sleep mode most of the time.

Environmental Sensor Bus (EBS) architecture [16] provided allow developer to integrate custom made analog and digital smart sensors to the system. Hence, additional user developed sensors can be incorporated to the system for data collection without replacing the existing instrument.

B. Server Tier – Embedded Computer System

Robin Z530L, an embedded Nano COM Express™ computer module designed for high performance computing with low power consumption and small footprint used as server tier to store database and log data shown in Fig. 2. The computer module includes 1.6 GHz Intel® Atom™ Z530, 4 GB SSD, 1 GB RAM runs Debian-based Linux OS [17]. Daisy, COM Express compliant carrier board to provide various interfaces such as USB and GLAN connectivity, SATA and MicroSD storage slots, Mini PCIe with SIM holder, TV-out, HD-Audio jacks, GPIO header and power connector for Toradex Robin COM module [18].

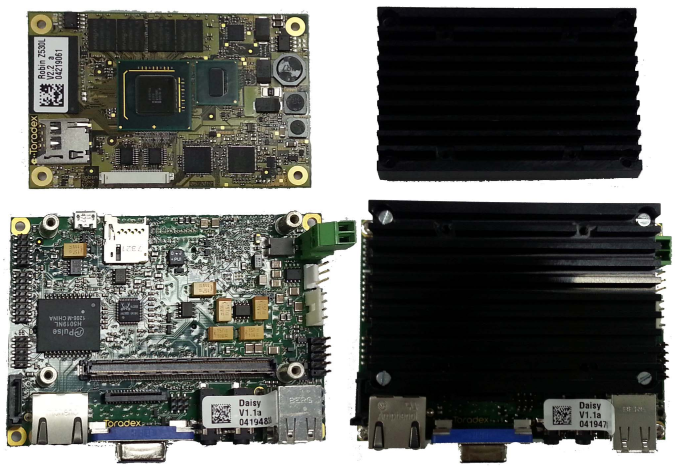

Fig. 2. Nano COM Express™ module, Robin Z530L with Daisy baseboard and heatsink

XServe, server tier application [19] developed by Memsic installed to collect data from sensor nodes and route data within the mesh network with higher level services to parse, transform and process data as it flows between the mesh and external applications. The application allow user via terminal interface to access the network directly or through XML RPC command interface.

Custom script written in C to periodically check the local database for new data entry and transmit the data via internet connected on-board GSM module to cloud server via HTTP POST. Data transmitted in JSON format for minimal data payload as shown in Listing 1. Periodic execution of the script every minute are sufficient to push weather data, node sensor data and sensor network health to cloud server shown in Fig. 3.

Listing 1. Sample JSON object structure for weather data.


```
{ "station":"Paddy-Field-1", "node":123,
  "time":"1436245627", "temp":27.7, "hum":57,
  "press":998.1, "solar":127, "dew":18.1, "rain":0,
  "winds":15, "windd":195, "soilm":50, "soilt":25 }
```


Weather parameters in JSON object explained in Table I.

TABLE I. EXPLANATION OF KEYS IN JSON OBJECT

station	String to identify distributed local base stations
node	String to identify WSN nodes
time	Time of reading in UNIX timestamp
temp	Temperature in degree Celcius
hum	Air humidity in percentage
press	Barometric pressure in mm/Hg
solar	Solar radiation in W/m^2
dew	Dew point in degree Celcius
rain	Rainfall in mm
winds	Wind speed in m/s
windd	Wind direction in degree
soilm	Soil moisture in cbar
soilt	Soil temperature in degree Celcius

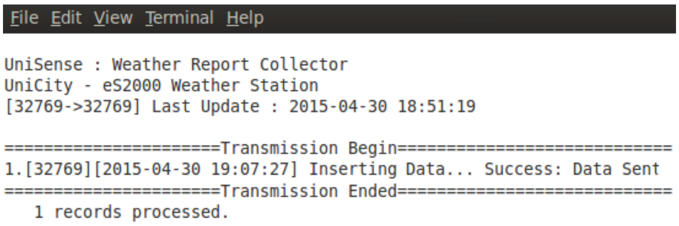

Fig. 3. Cron job set to periodically push data to server.

C. *Cloud Tier – Server backend*

Cloud tier consist of a server hosting web server and centralized database hosted by cloud service provider. Integration of cloud-based server allow monitoring and collection of sensor data from WSN base stations though out the globe to a centralized database as well as serving of large number of clients globally. Server tier device used to store database often at risk of data corruption during power failures and extended use of the system. Cloud-based system provides cost effective, reliable and scalable to store and manage data [20].

Architecture for backend cloud server separated to 2 main layers as shown in Fig. 4,

1) *Interface layer :* covers PHP and Apache web server
- Handles the HTTP POST/GET request from server tier devices and web application clients.
- Insert and request data from database layer with insert( ) and fetch( ) command respectively.

2) *Database layer :* covers MySQL database server
- Stores data received by insert( ) command and provide data in respond to fetch( ) command

Web application request for data handled by interface layer.

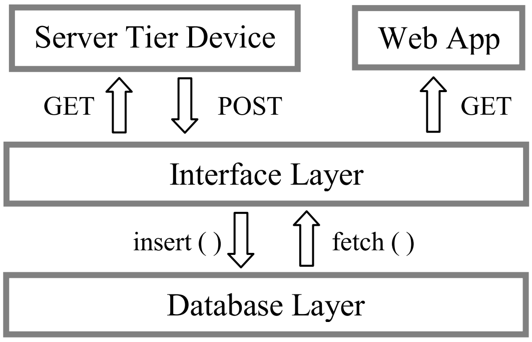

Fig. 4. Block diagram of backend server architecture.

D. *Client Tier – Web interface for remote users*

Web application were developed to graphically present the collected weather data on Google Map. The website display all the WSN base station on the web browser as shown in Fig. 5. All weather parameters gathered at local WSN base stations will be replicated to centralized cloud database, enable users to access live data from distributed weather station.

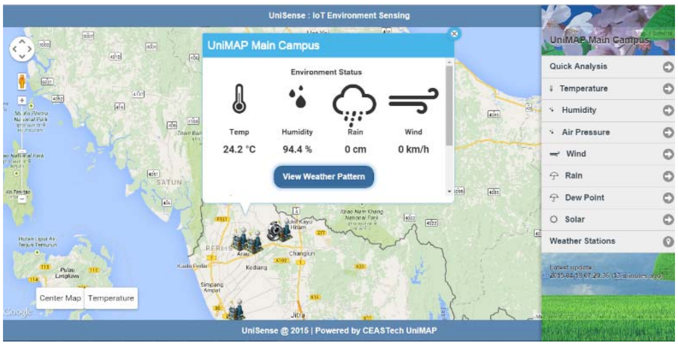

Fig. 5. User web interface

User can view the dynamically generated graphs for each weather parameters, such as temperature, humidity, barometric pressure, solar radiation, rainfall, wind speed and direction stored in the central database as shown in Fig. 6.

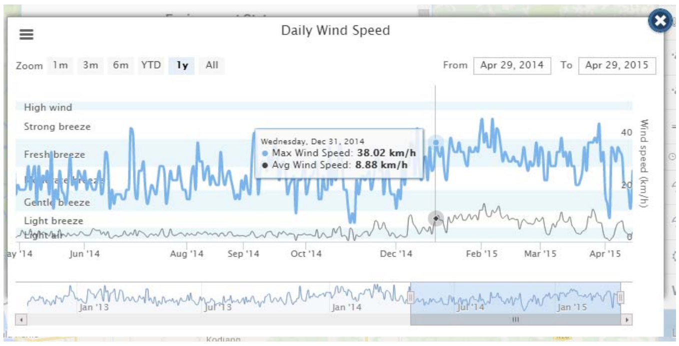

Fig. 6. Responsive graph of historical data for wind speed.

III. CONCLUSION

In this work, we propose system architecture and implementation of cloud-based remote environment monitoring system with distributed weather stations. An embedded system developed for local server that collect the environmental data and forward the data to the cloud.

Through this research, remote environment monitoring system offer users opportunity to view live environmental data from distributed weather stations across the state. Live network health status data from local wireless network allow system administrators to remotely monitor wireless network and troubleshoot the system remotely.

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REFERENCES

[1] "General Climate of Malaysia", Malaysian Meteorological Department. http://www.met.gov.my/index.php?option=com_content&task=view&id=75, (April 20, 2015).

[2] C. Hogan, "Meteorology", http://www.eoearth.org/view/article/154587, (April 20, 2015).

[3] R. Mendelsohn, P. Kurukulasuriya, A. Basist, F. Kogan, C. Williams, "Climate analysis with satellite versus weather station data.", Climatic Change, 81(3), pp. 71-83, 2007.

[4] D. Puccinelli, M. Haenggi, "Wireless sensor networks: applications and challenges of ubiquitous sensing," IEEE Circuits and Systems Magazine, vol.5, no.3, pp.19-31, 2005.

[5] D. S. Arjun, A. Bala, V. Dwarakanath, K. S. Sampada, B. B. Prahlada Rao, H. Pasupuleti, "Integrating cloud-WSN to analyze weather data and notify SaaS user alerts during weather disasters," 2015 IEEE International Advance Computing Conference (IACC), pp.899-904, 12-13 June 2015.

[6] Chebbi, W., Benjemaa, M., Kamoun, L., Jabloun, M., Sahli, A., "Development of a WSN integrated weather station node for an irrigation alert program under Tunisian conditions," 2011 8th International Multi-Conference on Systems, Signals and Devices (SSD), pp.1-6, 22-25 March 2011.

[7] A. Baggio, "Wireless Sensor Networks in precision agriculture", Proceedings of REALWSN'05 Stockholm Jun 20-21, 2005.

[8] S. M. Saad, L. M. Kamarudin, K. Kamarudin, W. M. Nooriman, S. M. Mamduh, A. Zakaria, A. Y. Md Shakaff, M. N. Jaafar, "A real-time greenhouse monitoring system for mango with Wireless Sensor Network (WSN)," 2014 2nd International Conference on Electronic Design (ICED), pp.521-526, 19-21 Aug. 2014.

[9] G. Bakul, D. Singh and Daeyeoul Kim, "Optimized WSN for ECG monitoring in ubiquitous healthcare system," 2011 4th International Conference on Interaction Sciences (ICIS), pp.23-26, 16-18 Aug. 2011.

[10] L. Capezzuto, L. Abbamonte, S. De Vito, E. Massera, F. Formisano, G. Fattoruso, G. Di Francia, A. Buonanno, "A maker friendly mobile and social sensing approach to urban air quality monitoring," 2014 IEEE Sensors, pp.12-16, 2-5 Nov. 2014.

[11] G. Vellidis, V. Garrick, S. Pocknee, C. Perry, C. Kvien, M. Tucker, "How Wireless Will Change Agriculture", Proceedings of the Sixth European Conference on Precision Agriculture (6ECPA), Greece, pp.57-67, 2007.

[12] Yazeed Al-Obaisat and Robin Braun, "On Wireless Sensor Networks: Architectures, Protocols, Applications, and Management", Auswireless Conference, 2006.

[13] K. G. Srinivasa, Siddiqui, Nabeel, Kumar, Abhishek, "ParaSense -- A Sensor Integrated Cloud Based Internet of Things Prototype for Real Time Monitoring Applications," 2015 IEEE Region 10 Symposium (TENSYMP), pp.53-57, 13-15 May 2015.

[14] Memsic, Inc., eKo Weather Station Suite Datasheet, 2007.

[15] Crossbow Technology, Inc., XMesh User Manual, 2007.

[16] Memsic, Inc., eKo ESB Integration, 2007.

[17] Toradex, Robin Z5xx Datasheet, 2011.

[18] Toradex, Daisy V1.1 COM Express Baseboard Datasheet, 2013.

[19] Crossbow Technology, Inc., XServe Users Manual, 2007.

[20] R. L. Grossman, "The Case for Cloud Computing," IT Professional, vol.11, no.2, pp.23-27, March-April 2009.