Internet of Things: *Sensor to Sensor Communication*

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***Abstract*— Rapidly growing Internet of Things (IoTs) concept have given rise to the concern regarding inter- communicability of sensor nodes practicing a multitude of standard and proprietary wireless communication protocols. A multi wireless communication protocol transceiver can facilitate sensor node to sensor node communication for a better quality of service and decision making in the IoTs environment. In this project, a multi wireless communication protocol receiver is designed and tested in a smart building monitoring system that collects and analyzes ambient data. The key objective of this project is to bridge the communication gap between sensor nodes especially in terms of wireless communication protocol. In overall, this project has successfully demonstrated a smart receiver concept that allows multi-channel communication between the sensor nodes with Zigbee, Bluetooth and WiFi communication protocols.**

Keywords— Internet of Things, Tranceiver, Inter-Communicability.

I. Introduction

IoTs is the modern world's revolutionary concept that ideally connects both inanimate and living things via the data collected using sensor nodes that can transmit the data to a local system or the internet using wireless communication for control and automation as well as cost saving[1]. Thus, IoTs concept leads to the requirement of inter-communicability and inter-operability of wirelessly communicating sensor nodes. These nodes are manufactured by different companies that practice a wide variety of communication protocols such as Zigbee, ANT+, Bluetooth Low Energy (BLE) backward compatible Bluetooth 3.0 and WiFi[2].

It is practically impossible to design all IoTs nodes to use similar communication protocol as each individual node require different data rate, range and power requirement based on their respective applications[3]. Healthcare smartwares such as smart bands that require low power consumption usually utilize BLE protocol for communication. Smart phone communication with the IoTs environment uses WiFi for better speed and data rate.

Each individual sensor cell that makes up a complete related system needs to communicate between each other for better decision making. The absence of inter-communicability of sensor nodes will cause the processing mechanism to neglect certain range of data for proper activation of actuator mechanism in the IoTs environment. For example, in a room that requires warm lighting, where the window curtain controller is from manufacturer A using Zigbee and the lights are from manufacturer B using BLE, there will be a need for a common communication mechanism for the nodes to relay the rooms current characteristics compared to the required characteristics for the nodes to work together in achieving the common goal.

A multi-protocol transceiver as illustrated in Fig.1 that channel communication between sensor nodes that practice a multitude of communication protocol based on their energy, speed or data rate requirement, will be the key for rapid development and realization of IoTs which is expected to have 50 billion connected devices by 2020[4].

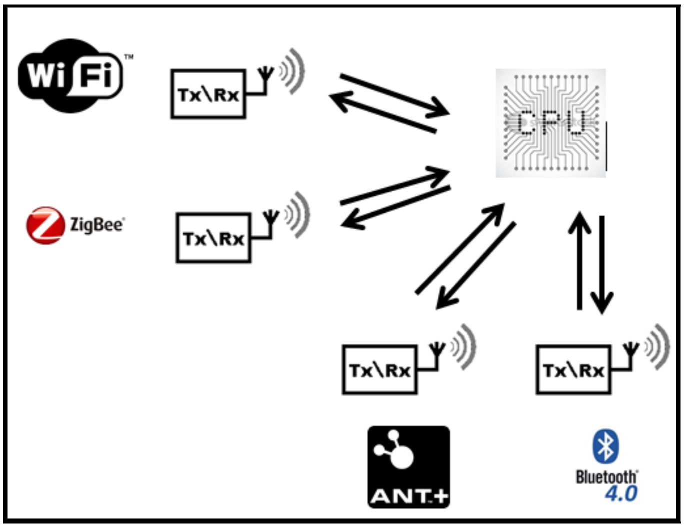

Fig. 1. Multi-Protocol Transceiver Concept

The impact of a multi-protocol transceiver to the modern wireless communication is strongly emphasized in [5], [6], [7] and [8]. J. Kaur and M. Singh [5] proposed a multi-protocol gateway that receives data from RF, Zigbee and Bluetooth protocols and convert it to GSM protocol as a medium for manufacturers to decide wireless communication technology of their products based on the requirements instead of using one technology for all applications. M. Ruta et al. [6] presented an approach of using hybrid Zigbee and Bluetooth protocol in facilitating communication between nodes by utilizing the

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characteristic advantage of both protocols. H. C. Sanchez et al. [7] proposed a multi-protocol gateway as a unified framework for the integrated migration of proprietary and specific protocol devices using KNX, Zigbee, Bluetooth, WiFi and Ethernet in the field of Telecare, Environmental Monitoring and Control. E. Cano and I. Garcia [8] discussed the design of a gateway utilizing both Bluetooth and Zigbee protocols as a flexible and expandable communication platform.

This paper discusses the implementation and beta testing of a multi-protocol receiver concept in a smart building monitoring system. The paper is structured as follows:- Section II presents the overall multi-protocol receiver concept. Section III discusses the beta test of the multi-protocol receiver. Finally, conclusion and future work is documented in Section IV.

II. Multi-Protocol Receiver Concept

To start materializing the multi-protocol transceiver, a multi-protocol receiver was designed and tested in a smart building monitoring system as visualized in Fig. 2. As shown in Fig. 3, the front end receiver consists of 6 receivers that can retrieve data simultaneously from different communication technologies. The multi-protocol receiver was a combination of WiFi[9] and Zigbee using xBee[10] via Arduino module[11], Bluetooth 3.0 module[12] and Zigbee interface modules such as Memsic receiver[13], [14] and National Instrument receiver[15] connected to a PC running Labview software and MySQL database. As shown in Fig. 2, a smart building monitoring system is designed using Labview to process the received data and store the processed data in the local database as well as transfer it to the cloud via Hyper Text Transfer Protocol (HTTP) for back end data analysis and representation as shown in Fig.3.

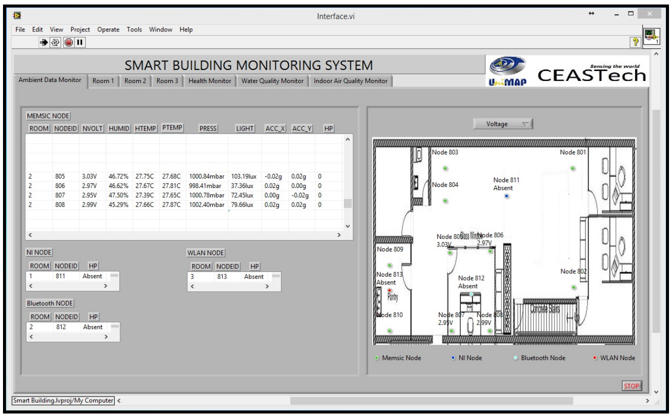

Fig. 2. Smart Building Monitoring System Interface

A. Sensor Nodes

Aiming for a simple and complete multi-protocol receiver design, sensor nodes that utilize different communication protocols with relative functional significance to a smart building monitoring system were chosen from commercial products as well as designed off the shelf as shown in Fig. 3.

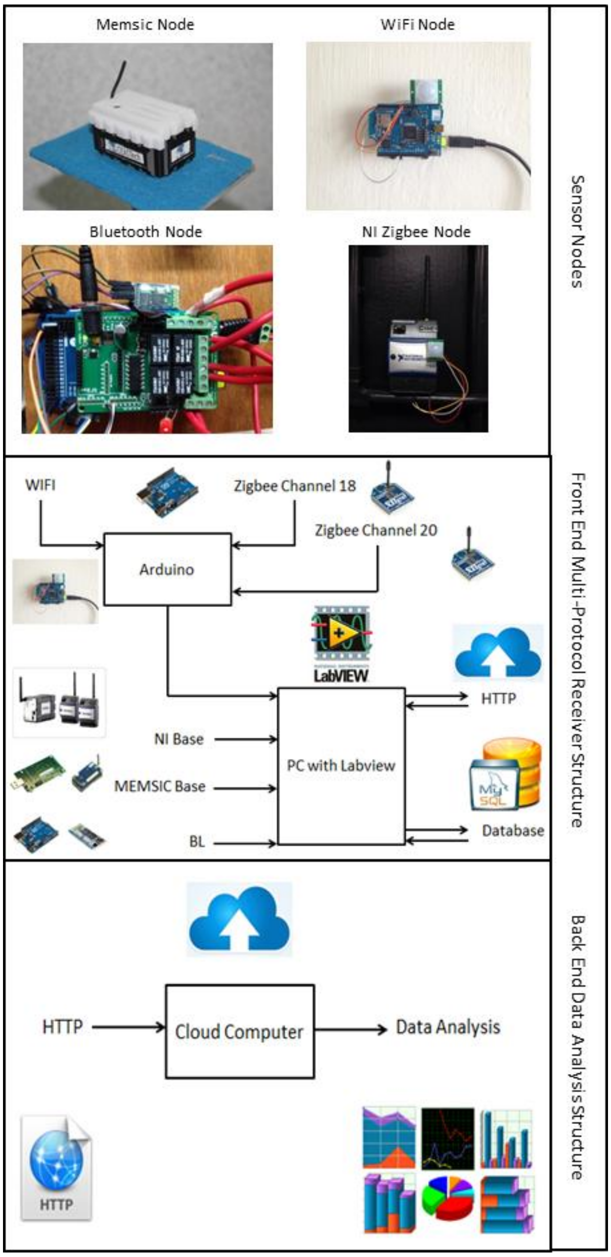

Fig. 3. System Hierarchy

To be specific, human presence detecting nodes were designed using PIR sensors[16] together with nodes utilizing Zigbee, Bluetooth and WiFi. The Zigbee based human presence detecting node was designed with NI WSN Zigbee node[17]. While, the Bluetooth and WiFi based nodes were designed by integrating the communication protocol specific modules to Arduino boards.

Besides that, water quality monitoring node was designed with sensor probes together with Arduino node that utilize xBee for communication. The designed nodes were programmed to collect, encode and send the data. Rather than that, commercial Memsic Iris WSN nodes[14] with MTS400 sensor boards[18] were also used in the system to gather ambient data.

room	nodeid	voltage	humid	humtemp	prtemp	press	lightc	accel_x	accel_y	time	human_presence
1	804	3.14	47.67	29.02	29.42	1002.08	217.51	0.50	-0.70	2015-03-18 18:50:53	1
2	807	3.12	53.53	28.90	29.14	997.94	96.67	0.78	-2.24	2015-03-18 18:50:56	1
1	803	3.07	45.60	29.74	29.65	998.13	138.48	0.96	-0.30	2015-03-18 18:50:59	1
2	806	2.63	53.76	28.50	28.85	995.23	203.55	-0.14	-0.06	2015-03-18 18:51:00	1
1	802	3.12	45.18	29.88	29.90	999.79	240.71	-1.46	0.52	2015-03-18 18:51:02	1
2	808	2.60	53.17	28.57	28.84	998.06	217.35	0.00	0.00	2015-03-18 18:51:03	1
1	801	3.15	44.46	29.73	29.79	999.44	264.36	-0.32	1.14	2015-03-18 18:51:04	1
1	803	3.08	45.60	29.74	29.65	998.22	138.48	0.96	-0.30	2015-03-18 18:51:06	1
2	806	2.62	53.76	28.50	28.85	995.14	203.55	-0.14	-0.06	2015-03-18 18:51:08	1
1	802	3.12	45.18	29.88	29.90	999.68	240.71	-1.44	0.50	2015-03-18 18:51:10	1

Fig. 4. Organization of Collected Data in the Database Table

B. *Front End Multi-Protocol Receiver Structure*

To practically prove the possibility of designing a multi-protocol receiver, the front end receiver structure was designed by incorporating Zigbee, Bluetooth and WiFi receivers to a reconfigurable design connected to a PC with Labview as the processing mechanism.

The processing mechanism, as required for a multi-protocol transceiver concept was designed to localize data received based on the transmitting nodes as well as segregate, process and analyze the received data. The design was done with proper consideration to include a multi-protocol transmitter in the future.

The processed data is stored in a MySQL based local database as illustrated in Fig.4 for further minor analysis as shown in Fig.5. The database is designed with a single table that contains rows with overall processed data from various nodes utilizing different communication technologies. Whereas, for the major analysis and visualization purposes the data is send to the cloud computer.

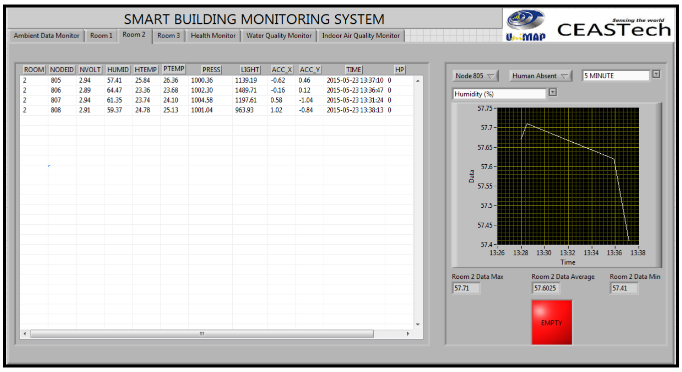

Fig. 5. Data Visualization and Analysis

C. *Back End Data Analysis Structure*

To make the data virtually available in all corners of the globe, the back end data analysis structure was designed in a cloud computer. The design includes storage of data in a MySQL based database as shown in Fig.4, visualization of data as well as analysis.

The visualization and analysis of data is executed in two internet accessible methods via web based graphs as illustrated in Fig.6 and also Android based application as shown in Fig.7. In particular both analysis methods analyze the ambient data variation in the presence and absence of humans in the rooms of the building.

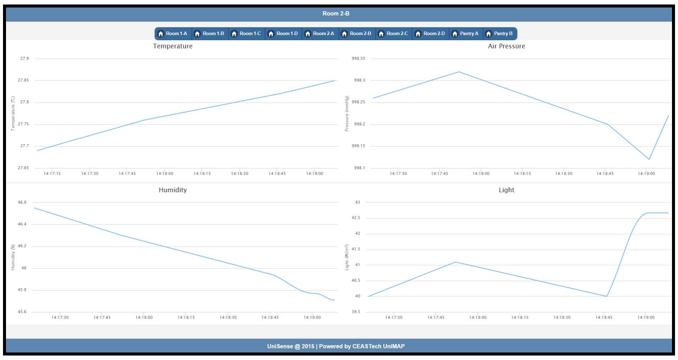

Fig. 6. Web Based Graphs

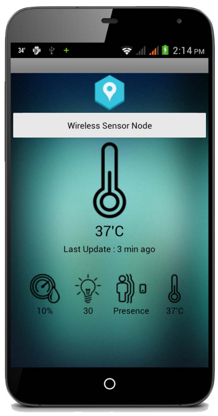

Fig. 7. Android Based Application

D. *Receiver Future Structure*

The receiver design is planned for further compression into an embedded design as illustrated in Fig.8. The Arduino based receiver modules are planned to be developed into a smart embedded system that support multiple wireless communication protocol based expansions. On the other hand, the PC with Labview is planned to be replaced with a smart embedded computer or single board computer.

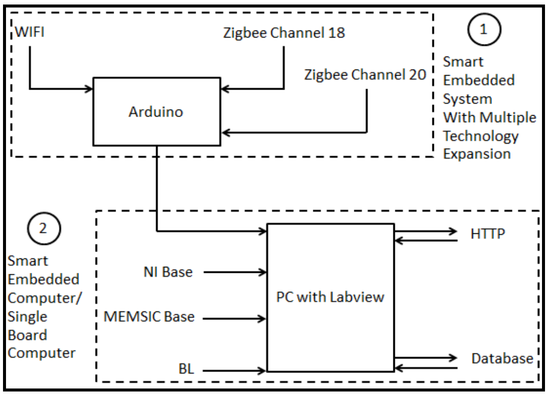

Fig. 8. Future Design

III. MULTI-PROTOCOL RECEIVER TEST

For testing purposes of the multi-protocol receiver, sensor nodes with different connectivity transceivers namely Zigbee, Bluetooth and WiFi were placed around the rooms as shown in Fig. 9 on a height of more than 1 meter. Nodes utilizing multiple communication protocols were used for the experiment to assess and prove the capability of the multi-protocol receiver to receive, segregate and process the data from multiple nodes communicating with different communication protocols and programmed for different applications in a centralized manner as shown in Fig. 10. Each individual tested 2.4GHz communication protocol can be assigned as the communication mechanism of a device based on application with proper evaluation on advantageous characteristics of the protocol.

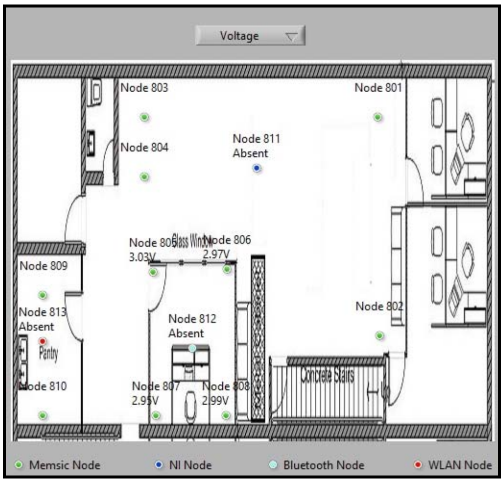

Fig. 9. Node Position Map

ROOM	NODEID	NVOLT	HUMID	HTEMP	PTEMP	PRESS	LIGHT	ACC_X	ACC_Y	HP
2	805	3.03V	46.72%	27.75C	27.68C	1000.84mbar	103.19lux	-0.02g	0.02g	0
2	806	2.97V	46.62%	27.67C	27.81C	998.41mbar	37.36lux	0.02g	0.00g	0
2	807	2.95V	47.50%	27.39C	27.65C	1000.78mbar	72.45lux	0.00g	-0.02g	0
2	808	2.99V	45.29%	27.66C	27.87C	1002.40mbar	79.66lux	0.02g	0.02g	0

Fig. 10. Live Data

IV. CONCLUSION AND FUTURE WORK

The proposed multi-protocol transceiver will be the primary key in the success of IoTs implementation via the removal of highly obstructing protocol barrier between IoTs nodes. In the current development stage, the multi-protocol receiver can receive data from multiple nodes via Zigbee, Bluetooth and WiFi protocols, differentiate each data packet based on the sender and process the received data altogether. For future work, a multi-protocol transmitter is in the early stages of development. After completion, both the receiver and transmitter parts will be integrated and further developed with a centralized processor to channel communication between sensor nodes that use different communication protocols as an aid to complete the IoTs environment.

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