A Web-Based Wireless Sensor System to Measure Carbon Monoxide Concentration

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Abstract **– Carbon monoxide (CO) concentration reflects the environmental quality of an area. An instrument that measures CO level is very useful for mitigation of effects caused by it due to industrial development. The inherent problem of CO measurement is wide distribution of this gas that continuous measurement is difficult to do. This research proposes a CO measurement system using wireless sensor. The system node developed includes a CO sensor, a data acquisition system, and a communication system from remote terminal unit (RTU) to a web server. The proposed model is a communication between a database saved with RTU microprocessor and a database saved in a web server. The web server comes with a program that inputs data into the web server database and displays them on a dashboard. System testing reveal an average error of 7.73 ppm compared to available standard instruments, while the Mean Absolute Percentage Error (MAPE) is 2.81%. Testing on database communication showed a transmission rate from RTU to web server of 10.6 second on average and it was also understood that it changes from time to time.**

Keywords — concentration; area; wireless sensor; error, communication

I. INTRODUCTION

Measuring carbon monoxide (CO) concentration in a living are is a very important issue. Carbon monoxide concentration in a living area reflects the environmental quality of that particular area as CO relates to both business and industrial activities. Availability of CO data from a monitoring program may help mitigate the effects of industrial activities on the well-being of people living in an area [1].

Numerous methods of environmental gas concentration monitoring have been employed. These methods always strive for accuracy, easy operation in the field, measurement costs, and number of samples. A method may come with better accuracy, but perhaps does not provide cost efficiency and ease in taking samples [2]. Incorporation of information technology for that case can help inform parties concerning data on gas concentration. Use of internet network will reduce cost and shorten the time of gas concentration measurement in a wide area.

The rate of change in carbon monoxide concentration in the environment is not linear and is affected by many factors. Nowadays, industrial development is growing rapidly. Industrial machines have greatly contributed to environmental pollution with their carbon monoxide output. Measurement of is usually only carried out at one point in a wide area and it is done manually. This method is incapable of describing CO concentration in real-time at the measured point as gas has an inherent property of keep on changing its concentration. The use of wireless sensor technology takes care of the problem with distance and data continuity [3]. Measurement of CO using wireless sensors in this research is expected to anticipate changes in CO concentration, and that one point and the others can be connected as to describe the whole dynamic of CO concentration changes in an area.

Some communication media have been developed to help improve efficiency in CO concentration measurement. A system of CO concentration measurement has integrated a measurement instrument into a cellphone [4]. This device is capable of measuring CO exposure on smokers, but is not yet able to send recorded data automatically for a computer based monitoring and processing. Integration of gas sensors into web-based internet has provided ease of data processing covering wide areas. This model allows integration of a sensor network into a commercial network at low cost [5]. A web-based measurement system facilitates autonomous parameter monitoring and control by users given access. Moreover, cloud computing will help easy data distribution to other users. This research proposes a web-based CO concentration measurement system.

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II. SYSTEM REALIZATION

This research provides an example of single-node CO sensor placed in an area for CO source monitoring. Experimentally, adding node can easily be done by placing the same device and providing a unique data transmission code to be recognized by the web server. This makes it possible for the system to access wide areas adjustable simply by adding more required sensors.

Web-based wireless Sensor system for carbon monoxide concentration monitoring consists of: a CO sensor node, a web server, and a user computer. Each device is connected to a GSM modem for data communication via the internet network. This commercial route is chosen for its low cost. Access area is not limited as GSM based broadband internet is already integrated into our community. Devices connection to the wireless sensor system built is shown in Figure 1.

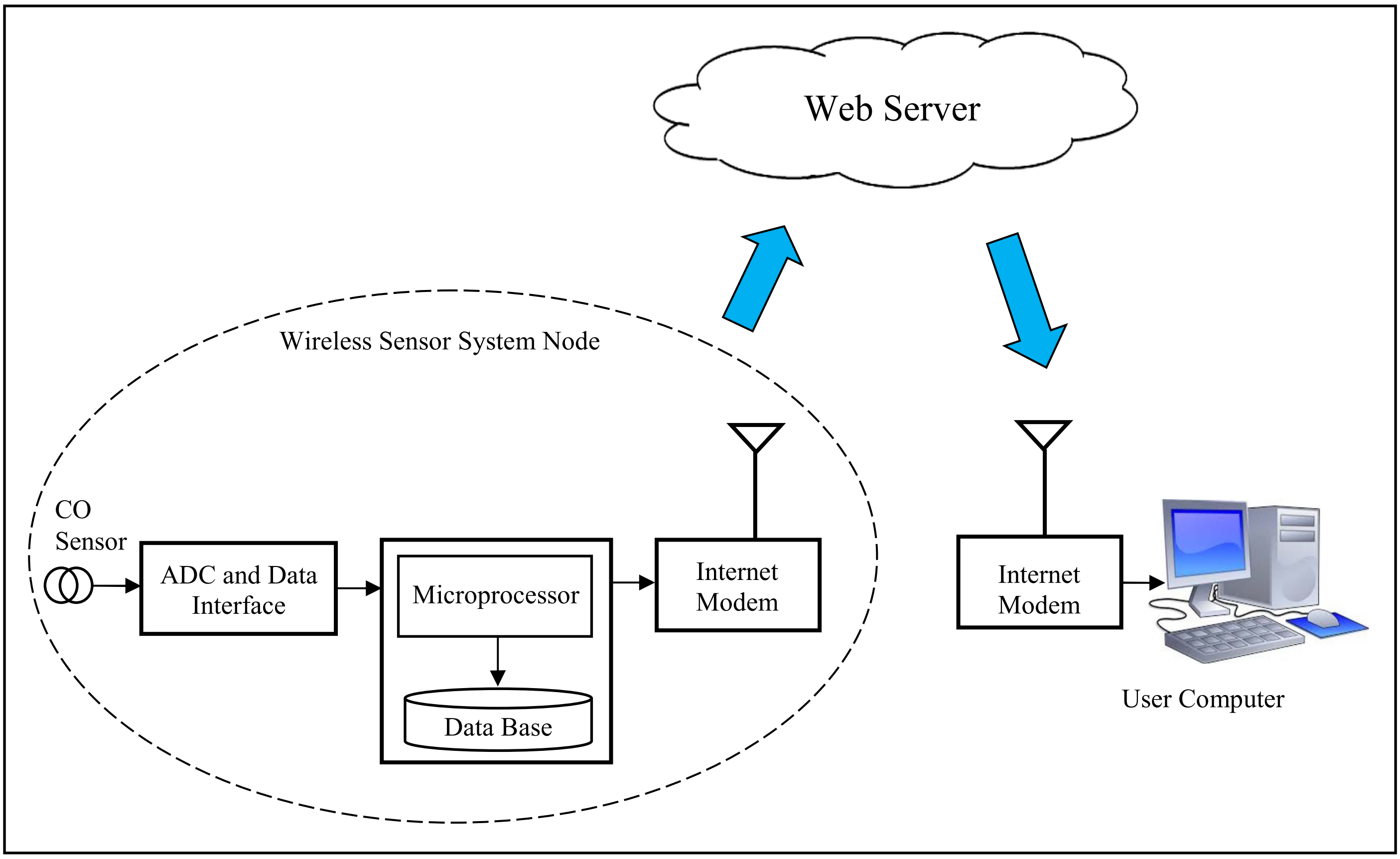

Fig. 1. Overview of web-based carbon monoxide wireless sensor system.

The system works as follow: A CO sensor alters gas concentration unit into an analog electrical voltage. This signal is then converted into digital by the Analog to Digital Converter (ADC). An ATSAM3X8E microcontroller is used to control the ADC and serves as data interface to the microprocessor. Each datum read by the microprocessor is then saved in the database and sent to the web server with the help of an internet modem. These data can be viewed in the user computer given access to that web server.

The electronic circuit developed for this research is given in Figure 2. This system employs CO sensor of type SnO_2 semiconductor. Electrical conductivity of SnO_2 sensor in clean air is low. CO oxidation coming into the semiconductor material causes oxidation that increases its electrical conductivity.

SnO_2 chips are heated at certain temperatures to ensure proper sensor performance. This heating is regulated by a relay controlled by the microcontroller. Absorbed CO by the sensor causes the gas to be ionized and tied to the crystal surface of the SnO_2 in the form of negative ions. Donor electrons on this chip surface ties oxygen ions and create positive ions in the spaces on that crystal surface that a surface potential is generated. This surface potential slows down the velocity of electrons on the crystal. The value of this electron velocity is the electrical current comparable to CO concentration.

An electrical circuit is used to convert changes in conductivity to generate output signal comparable to CO concentration detected by the sensor. Sensitivity to CO concentration correlates to the temperature of semiconductor chips. Therefore this sensor is equipped with a heater to improve its performance. A load resistor of 10KΩ is installed on the circuit to alter electrical current into voltage.

The ADC circuit developed in this research has a conversion range of 16 bit of type ADS1115. Analog data read by the sensor is transformed into digital if they are in the range of 0 – 65.535. Reading this data on ADC requires the use of ATSAM3X8E microcontroller with I2C (Inter-Integrated Circuit) protocol. The ADC reading system is controlled by 2 lines of Serial Data Line (SDA) and a Serial Clock Line (SCL). Data readings from ADC are then sent to the microprocessor via a serial COM communication system. The C language has been used to program the microcontroller.

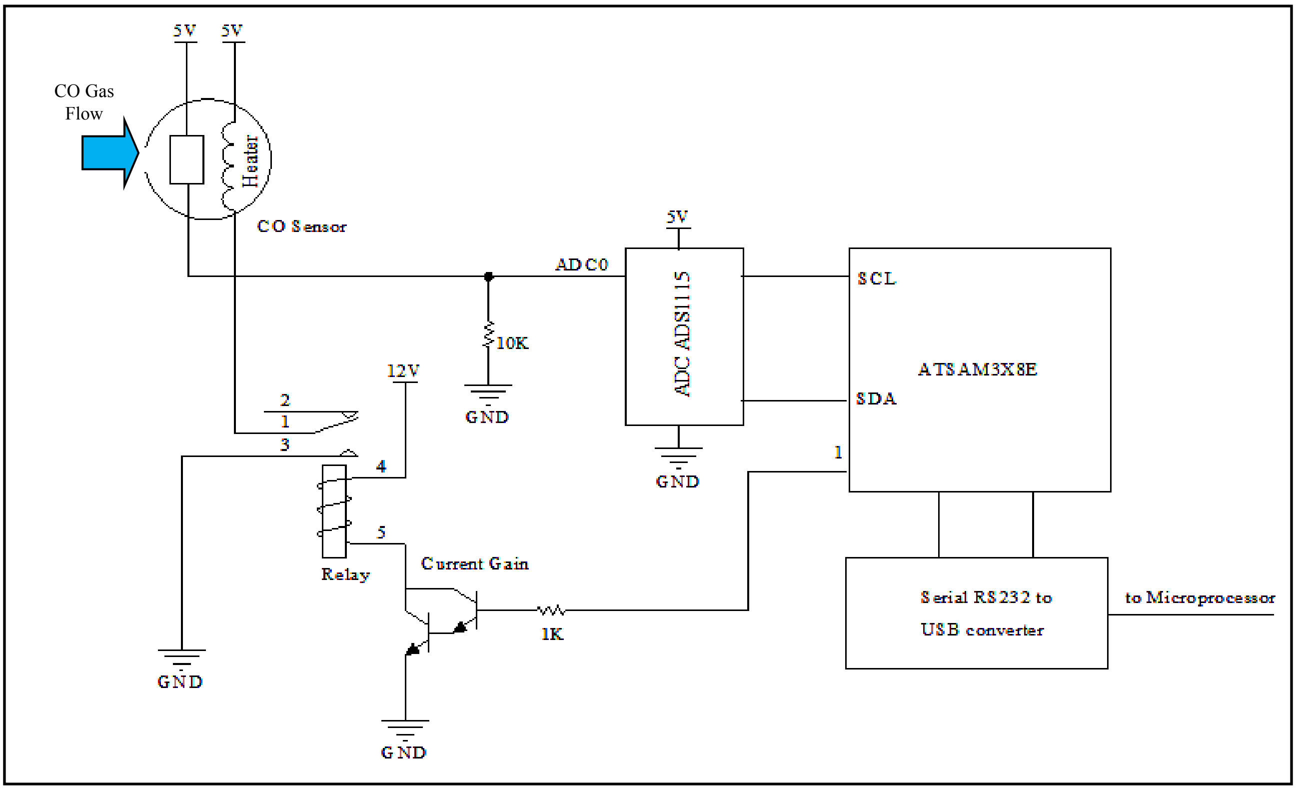

Fig. 2. A Carbon monoxide sensor and interface circuit.

In the microprocessor, a program written using a high visual programming laguage is made. In order to read the data sent by ATSAM3X8E microcontroller, sockette COM programming is used using the Universal asynchronous receiver-transmitter (UART) protocol. This protocol sets both the microcontroller and the microprocessor at the same baudrate of 9600 BPS. Data from the microcontroller are data strings. This data string model allows unlimited data bit width. The 16 bit ADC facilites 5-character to be sent. Once recieved by the microprocessor, these data are collected and converted into integers for mathematical operations.

The data received by microprocessor are ADC load data. This means that inverse transformation using sensor characteristic is required to display the data in the form of gas concentration. These acquired data are then saved in the database. During data acquisition, an additional system that connects data acqusition software and database is added. Each datum taken by the microprocessor are saved in the database in the following order: code number, time, and concentration. The default data pause is set at 1 minute. This data acqusition pause can be set as required.

A web-based data acquisition programming is used to read data sent by the microprocessor via an internet modem. Data in the database are sent one by one to the web server with the help of a separate programming written separately from the data acquisition system. A line signature is given for each datum successfully sent to the web server. This is meant to allow verification of the last data sent should the modem connection is interrupted, so that once connection is reestablished the next datum sent are continued from the last data sent prior to modem disruption.

A system of web-based data acquisition has been developed to save, process, and display CO concentration data. The architecture of the system developed consists of a *user service, a main program and an output dashboard,* as shown in Figure 3.

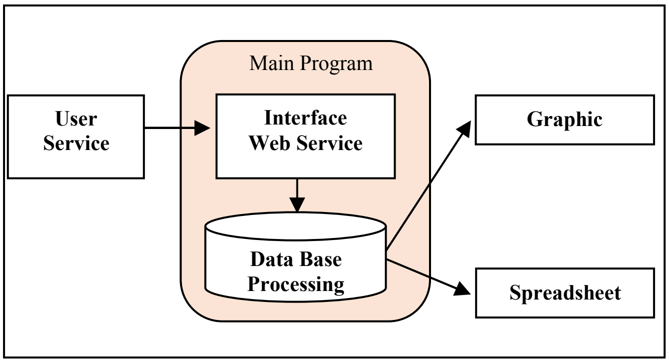

Fig. 3. Architecture of the web-based data acquisition system.

In this system, a user service is used to manage the web and access rights. The web service interface is built with a programming script saved in the web domain. It functions to receive data sent from the wireless sensor system in the field. Preprocessing results are CO concentrations. The following process is saving these data in the web-based server in line with the format sent by the wireless sensor system. Stored data in the database are then processed as outputs displayed in graphs and spreadsheets.

III. RESULT AND DISCUSSION

This research has successfully developed a CO sensor circuit, a data acquisition system, a data transmission system, and a web server to display measurement results on the internet. The sensor developed was characterized by measuring CO concentration against output of ADC ADS1115 read by the microprocessor. This characterization also involved curve fitting with a resulting 5th order polynomial fit, decreasing against concentration increases. These characterization fit was then used as the foundation for inverse transform using microprocessor programming to get concentration values for each ADC reading.

The first testing of the system developed was data transmission from RTU to web server. This testing included transmission rate by measuring time delay from the microprocessor bios to that of the web server. Each datum sent was assigned an identity at the database, and then matched with the ones at the RTU and web server. The time delay profile of this data communication is depicted in Figure 4.

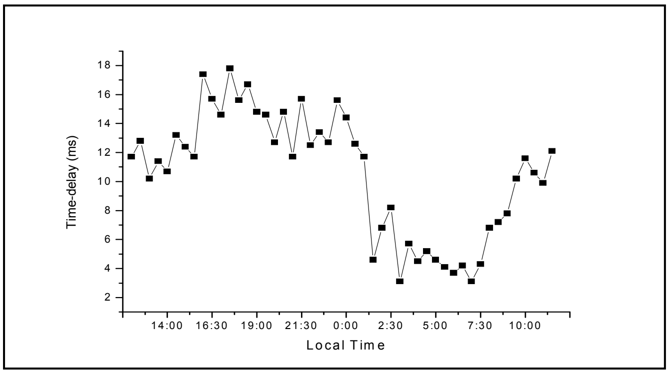

Fig. 4. Profile of data transmission rate against local time.

It can be seen Fig. 4 that there are changes in data transmission rate from time to time. This data transmission system depends on the broadband internet communication service and the internet bandwidth availability both on the internet hosting and website domain at certain times. It can also be seen that transmission rate correlates with local time. On the other hand, local time relates to internet traffic and broadband communication. During office hours, time delay is considerable as internet users are on its peak from around 10:00 a.m. to 10:00 p.m. The average transmission rate for this system is 10.6 seconds.

Calibration was carried out by calculating the errors of CO concentration measurement using RTU against that of standard measurement instrument, of which the data are available online. Calibaration results are shown as grapsh in Figure 5. This calibaration results involves statistical testings with an average error of 7.73 ppm with Mean Absolute Percentage Error (MAPE) showing a value of 2.81%. It was then inferred that errors are caused by sensor accuracy and environmental condition in the field. For example, the sensor is not capable of proper measurement at very low concentration that the resultting error is considerable. Another case is when the sensor heater, at some point, may not be able to warm up the sensors optimally, hence, sensors' sensitivity decreases.

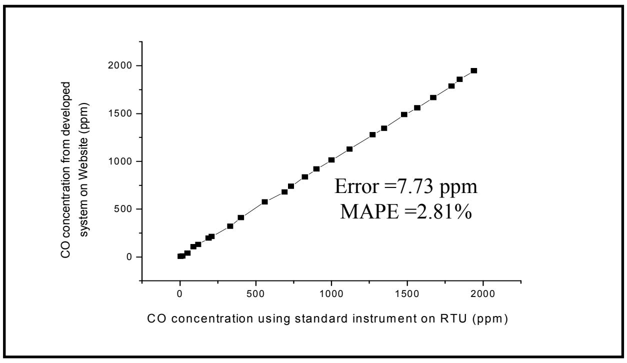

Fig. 5. Calibration result of the CO concentration measurement instrument.

Website design is oriented towards users' need. The website developed here is shown in Figure 6. The menus provided include user account for access management, node option for field measurement, data download, data backup, and graph display. Only users with granted access can download data do data backup. Downloaded data are in spreadsheets for easy processing. Every commercial hosting service comes with varying database capacity. Therefore, this system has is equipped with data back up and clear data options.

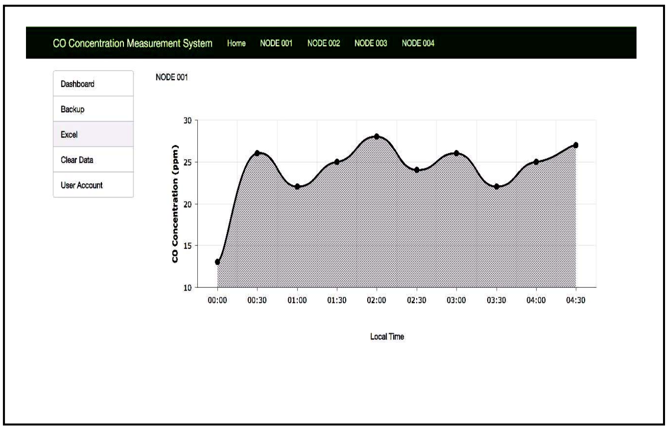

Fig. 6. Website layout of the CO concentration measurement instrument.

IV. CONCLUSION

A remote measurement system for carbon monoxide (CO) concentration measurement has been successfully developed using the wireless sensor technology. Readings of CO concentration have been integrated, saved, and managed via website. Data from sensors can be managed with an interface that helps communication between database at the Remote Terminal Unit (RTU) located in areas of CO sources and the database at the web server. System testing reveal an average error of 7.73 ppm compared to available standard instruments, while the Mean Absolute Percentage Error (MAPE) is 2.81%. Both values are affected by measured CO concentrations and sensor conditions in the field. Integration of wireless sensor system with website provides ease in CO concentration monitoring, as data can be downloaded in spreadsheets for users given access. Furthermore, saved data in the web server can also be backed up and/or deleted to save memory use and improve web server performance.

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