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Modern Techniques for Sensors Data Acquisition and Mobility

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ABSTRACT

Most of Sensor Networks (SN) or sensor systems have a main target. This target is the instantaneous collecting of data or sensors readings every second (or fraction of seconds) and transferring / sending this data to a main computer or network server. The techniques used to collect and transfer network data to the main computer plays a vital role in goodness / robustness of that monitoring system. This research aims to design and implement a mobile unit to collect data that are read from a collection of sensors within an environmental monitoring system. A new concept of portable data acquisition unit and how it saves the sensors readings that are collected from network nodes is explained in details in this research. In this research, the technique for collecting and storing the sensors data is presented by using modern memory card (microSD).

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Through the use of this storage media the sensors or network nodes can store their data from any location and at any time for processing and analyzing targets. Furthermore, we illustrate how to design a portable or mobile network node or unit to perform the required measurements of temperature (using three LM35 sensors) and air quality measurements (using MQ135 sensor). This portable unit containing a Data Logger can work independently and collect sensors readings and store them on a microSD memory card quickly and efficiently.

INDEX TERMS Sensor Networks (SN), Environmental/radiological monitoring systems, microSD memory card, LM35 sensor, MQ135 Sensor, Microcontrollers, and Big Data Aggregation

1. Introduction

Nowadays, a lot of sensor network/systems are used or applied in environmental monitoring and other diverse applications. To name but a few, examples are across Monitoring life and biological diversity in forests, monitoring environmental factors, monitoring water and air pollution, tracking fires and monitoring electric power plant operations.…etc. So that sensors networks contain special transducers or data conditioners with modern communications subsystems for environmental properties tracking / recording at diverse locations and systems.

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In general the monitored parameters may be Atmospheric pressure, wind direction or speed, temperature, humidity, even illumination and so on. Now the modern applications of environmental and radiological monitoring have specialized measurements of chemicals, toxic and pollutants concentrations, and vital body functions. As a result of these modern systems there are huge volumes of sensors readings or data that require a reliable system for data collecting, acquisition, processing and analyzing. In either of two fields, environmental or radiological monitoring systems, mainly the data sent is the sensor(s) readings. These huge volumes of data sent from sensing devices considered a lot of information that is the next great challenge for researchers. So that, system engineers and database administrators are continuously looking for new and smart tools for data collection and retain.

One of the most modern tools that used for data aggregation is the microSD (secure digital) memory card [1]. Actually this storage media could be benefitted for sensor data collecting and recording in the cases of malfunction or a network node failure. Moreover in normal cases, this storage media could be used to get redundant (backup) data and data retention.

Data redundancy appears when dealing with a database in which the same item of data is saved in two separate rows / places. Data redundancy means that the same data are not present in one and only place. It. Redundancy could be related to hardware such as auxiliary storage and related to software as repeated fields in the database. Data retention, also called records retention, is the continued storage of important and critical data or information.

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In this paper we illustrate and explain how to use the microSD memory as a data logger tool to continuously collect / backup the sensors readings in normal or up normal (may be critical) cases. Using this technique we can benefit of a modern design of mobile sensor nodes that could be implemented for environmental monitoring systems and a lot of industrial data loggers. This paper includes five topics or parts. These parts start with "Introduction", an introduction about the definition of the environmental monitoring systems and the use of sensor networks which deal with a huge or big data collected from the sensors. The second part, "Big Data Definition", in environmental sensor systems, there are large quantities of readings or data generated by sensors in one second that is considered big data where we illustrate the problems resulting from data (big data) aggregation. So we lock for good and new tools for data aggregating or collecting. In third part, "Modern Techniques and Protocols of Data Aggregation", we discuss the used techniques for data gathering and the shortage of these techniques which direct us to the desired tool for sensor data collecting in monitoring systems. In fourth part" Secure Digital, SD Memory Cards", we demonstrate the memory card (its characteristics ,families, form factors and speeds) as one of the modernist media or tool to gather and save the large quantities of sensor readings. The last topic or part of our paper deals with the practical steps to build the electronic circuit to interface the SD memory card with the microcontroller in order to gather the sensors reading from the monitoring system.

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2. Big Data Definition

Big data is often featured by three Vs [2]; the first is the severe *volume* of data, the second is the *variety* of data types and the third is the *velocity* at which the data must be processing. Although big data doesn't equate to any specific volume of data, the term is often used to describe terabytes (equals 1024 gigabyte), petabytes (equals 1024 terabyte) and even Exabyte (equals 1024 petabytes) of data captured over time.

Volume refers to the amount of data, variety refers to the number of types of data and velocity refers to the speed of data processing. With respect to the 3Vs definition, the challenges of big data management result from the expansion of all three properties, rather than just the volume alone -- the sheer amount of data to be managed.

The main target of big data management is to ensure a goodness of data and accessibility for big data analyzing systems. Governmental agencies and other corporations follow database management strategies to get fast-growing pools of data, which generally include a lot of information stored in different file formats. These effective management strategies help companies to get valuable data in huge sets of unstructured or semi-structured data from many sources, such as call detail records, the software system logs and social media on internet sites.

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2.1 Dealing with the Big Data

Such copious data can come from thousands of different sources, such as industrial systems measurements, the measurements of scientific experiments or instantaneous sensors readings. It is known that the data may be raw (ore data) using some software tools before applying analytic processes. These data may also held in different file types/formats, in structured data, such as database records; or unstructured data such as text files; or just instant data from sensors. Furthermore, these big data perhaps contain different, simultaneous unintegrated data sources. As a result the big data analytics tools may attempt to check the data integrity to remove redundancy and null data entities inside tens of thousands of data records.

In environmental and radiological monitoring systems, especially in power stations, the number of sensors used can be as high as 10,000. Therefore, there are large quantities of readings or data generated by sensors in one second that is considered big data. As mentioned above, the analysis processes of these large amounts of data had programs and strategies related to the so-called big data management. Therefore in this research we are looking for an effective tool for data collection and storage not for data analysis that has been extensively discussed and researched.

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2.2 Data Aggregation Problems

As an important problem / dilemma in scientific or engineering fields is the sensor data gathering, where transmitted data are collecting at the sensor network nodes and then forwarded to a central node or station (sink node) for further processing.

In a wireless sensors networks (WSNs), each tiny sensor node is powered by a battery and uses wireless communications. This results in the small size of a sensor node and makes it easy to be attached at any location. Such flexibility greatly eases the costs and efforts for deployment and maintenance and makes wireless sensors network a competitive approach for sensor data collection comparing with its wired counterpart. But on the other hand, these tiny sensors are highly energy constrained due to their limited battery, storage, processing power and communication capacity. The worst case is when it requires these sensors to collect huge volume of data. Many previous research efforts have tried to achieve trade-offs for such data collection tasks. Simultaneously WSN suffers from a number of problems which obstructs data collection and integrity such as;

- Signal interference
- Signal weakness and cut off
- Data security and protection
- Powering by battery and energy cost
- Data routing among nodes

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In wired or wire line sensors networks there are different problems that may be appeared sometimes. These problems are abstracted in cables lengths and power losses in these cables. Therefore network designers and engineers are seeking for new and modern techniques to aggregate or collect the sensor data / readings on either of wireless or wired sensors networks quickly and accurately.

3. Modern Techniques and Protocols of Data Aggregation

Nowadays different techniques have been presented to reduce the consumed energy in sensors networks and nodes. Therefore data gathering / collection aim to reduce energy consumed by pulling data from different nodes to curb redundancy and excess data traffic. To prove superior data aggregation technique, there are two principles [3], [4];

- Less traffic and consumed energy by sending data from the nodes as it is being forwarded to the sink nodes. These techniques require that samples of data be collected periodically and transmitted back to a sink node where data is to be processed.
- Energy saving by using some nodes to sleep when they are not required in the sensing or data transmission tasks.

Currently there are many aggregation data techniques or protocols for different applications. Some examples such as, environment monitoring and continuous data collection, dynamic process and event detection, and instant tracking For sensor monitoring systems, the energy efficient Medium Access Control (MAC) protocols have been proposed. This protocol preserve energy by turning the nodes between active and sleep states (Node scheduling).

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It keeps approaches of data aggregation for periodic collecting process in sensors networks that monitor an area of interest. But if the network is deployed densely, data from great number of nodes may be redundant. To improve energy efficiency and the network lifespan, node scheduling technique/protocols can be used to put some (redundant) nodes to sleep. Data collecting can be done over the active nodes selected only by the protocol. One possible drawback of node scheduling methods is that area coverage may be incomplete when failures happen in communication and replacement node(s) is not awake (ready) immediately to replace the idle node right away. Furthermore, in other cases, it is preferred to use the data summaries, instead of its raw data, which are more valuable to the data analyst systems and tools.

Also timing issue is a key role in data aggregation process, real-time monitoring systems aim to retain an effective aggregation with minimal forwarding / transmission delay. For example, in nuclear power plants (NPPs), sensor nodes are dedicated to detect and measure process coefficients such as temperature, steam, oil and water pressure and varieties of industrial parameters. In such cases, the data and readings collected from the sensors network should remain as it is as possible. In other cases, we may need that some sensor readings lagging or delayed at intermediate nodes, while waiting for other data operations.

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With all these protocols and techniques to access the best cases of sensors data collection and aggregation, there are still problems which faced networks administrators / planners. These problems are requesting for easier, faster and reliable ways to collect / log data from the networks, especially monitoring networks. Those ways may solve the problems of sensors data redundancy, forwarding delay, node scheduling, and power efficiency. The following sections of this paper address one of the modern ways to collect the data from sensors quickly and efficiently for use in environmental / radiological monitoring systems.

4. Secure Digital, SD Memory Cards [5]

While searching about a simple and flexible media to store the sensor data, the modern **Secure Digital (SD)** memory card was strongly recommended. SD card is a non-volatile data memory card format which introduced by the SD Card Association (SDA) for use especially in movable or mobile devices such as digital cameras and mobile phones [6]. The standard was introduced in August 1999 by communion between SanDisk corp., Panasonic and Toshiba as an improvement over Multi Media Cards (MMC). These three companies also create the SD Association (SDA), a non-profit organization, in Jan. 2000 to promote and create SD Card standards. Today SDA has more 1000 member companies.

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4.1 SD Memory Card Families

As shown in figure-1 below, Secure Digital cards include four families which are formed in 3 different sizes. They are;

- The original Standard-Capacity SD card was introduced in 2000 with capacities less than 2GB.
- The High-Capacity SD card, from 2GB up to 32GB storage capacity, formed in 2006 as version 2.0 of the SD categories.
- The extended-Capacity SD card, more than 32GB up to 2TB storage capacity, introduced in Jan. 2009 as version 3.01 of the SD categories.
- The SDIO, it contains input and output pins with a storage area, was introduced in 2001 and it played a role of increasing SD host devices. Now SDIO cards are fully functional in that device supporting their input-output functions. SDA defined several SDIO Standard Functions Cards such as Wi-Fi, IrDA, Bluetooth, GPS (Global Positioning System), digital camera, modern digital modems, barcode machines / readers, FM / TV tuners, and Ethernet etc.

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4.2 SD Memory Card Form Factors

SD memory card (Stick) is formed in three form factors or sizes: (As shown in figure-2) the original Full SD, Mini SD and Micro SD cards. To use a smaller size card in a device built for a larger card, a reader (or called passive adapters) may be used. Today for many fields the micro SD card's is an ideal medium for more portable and embedded electronic devices.

Bus interface	Card logo	Bus logo	Bus speed	Spec version
Default Speed	SD SDHC SDXC	–	12.5 MByte/s	1.01
High Speed			25 MByte/s	2.00
UHS-I	SDHC SDXC	I	12.5 MByte/s (SDR12) 25 MByte/s (SDR25) 50 MByte/s (SDR50, DDR50) 104 MByte/s (SDR104)	3.01
UHS-II		II	156 MByte/s (FD156) 312 MByte/s (HD312)	4.00/4.10
UHS-III		III	312 MByte/s (FD312) 624 MByte/s (FD624)	6.0

Table-1: SD Memory Card Speeds

Commonly, this SD memory cards family is non-volatile, i.e. no external power is needed to keep the data or stored on it. Besides, it is also a solid-state component that doesn't contain movable parts to avoid breakdown. With new types of flash semiconductor chip, transcend SD cards own a great combination of fast data transfer, good flexibility, perfect security and incredibly minimum size. So that for these features, this memory slice was recommended to be used as a reliable storage media for the proposed monitoring network.

Speed	Mark	Minimum Serial Data (write speed)	SD Bus Mode	Application
UHS Speed Class	U3	30MB/s	UHS-II	4K2K Video Recording
	U1	10MB/s	UHS-I	Full HD Video Recording HD Still Image Continuous Shooting
Speed Class	CLASS10	10MB/s	High Speed	
	CLASS6	6MB/s	Normal Speed	HD and Full HD Video Recording
	CLASS4	4MB/s		
	CLASS2	2MB/s		Standard Video Recording
UHS: Ultra High Speed				

Table-2: SD card Speed Classes

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4.3 SD Memory Card Speeds

It is rated by its sequential speed of read or writes process. Small data speed could be considered as lower speed limits which is an important limiting factor in some cases. Few of early SD cards manufacturers specified the speed as a "X-times" ("×", x=150KB/S.) rate. This X rate is by comparing the average speed of data reading to the original speed of CD-ROM drive. Table-1 abstracts the common speeds of the different types of SD memory cards.

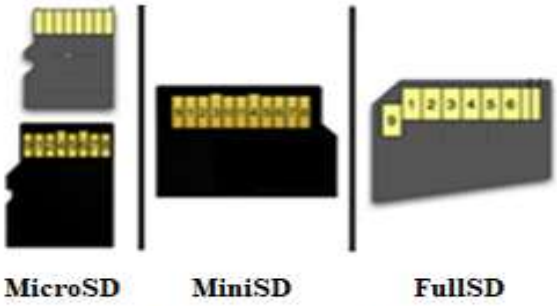

Figure-2: Memory card Shapes

This rate of speed was subrogated by the **Speed Class Rating**, which specify a minimum writing speed of the card. The SD Association invents a method to standardize the speed rates for the SD cards. These rates were abstracted as **'SD memory Speed Classes'** and denote the card utter minimum write speeds.
Cards may classify with Class 2 (Min. speed of 2MB/s), Class 4 (4MB/s), and Class 6 (6MB /s) and so on. The following table (Table-2) abstracts the speeds classes of SD memory cards.

4.4 MicroSD memory card

The **microSD,** figure-3, is a type of removable flash memory card used for storing information and it is sometimes referred to as **µSD** or **uSD**. The **microSD** (removable minimized) memory cards were called T-Flash or TF cards.

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TransFlash and microSD cards are typical or identical to operate in devices made for each other. SanDisk had imagined microSD when its chief technology officer and that of Motorola found that current memory cards were too large for mobile phones.

In 2005, Cellular Telecommunications Industry Association 'CTIA', introduced a smaller microSD form factor where Secure Digital High Capacity 'SDHC' of 2 GB and write speed of 17.6 Mbit/s. The SDA Association authenticated this microSD specification on July, 2005 [7]. Initially, modern or new microSD cards were existing in capacities of 32 up to 128 MB.

4.4.1 MicroSD Technical Specifications

. Cards are RoHS, Restriction of Hazardous Substances compliant parts.
. Voltage rate: 2.7~3.6 V. at temperature range 25~85 ^{o}C
. Durability for data write / delete: 10000 cycles
. Compatible with SD Association File System Specs. V1.1
. The card includes a write protection switch on the card reader.
. Multimedia Card upward compatibility via SD Host feature.

Figure-3: MicroSD Memory Card

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4.5. SD memory Card and Embedded Systems

The above topics of this research led to the design of the nodes and the required specifications for data collection being deliberately over engineered [8]. In 2008, the SDA had produced embedded SD card module to allow adding SD memory card on printed circuit boards (Figure-4)

Currently, a lot of new microcontrollers have built-in SPI capability that allows interfacing to SD flash memory card providing fixed or non-volatile storage. Even if a microcontroller lacks the SPI feature, the feature can be emulated by other ways of this module.

Although with SD card capacities as low as 128 **M**B, data logging and other functions can be added to a low-cost design. MicroSD with 11 mm by 15 mm physical size can fit into even the smallest systems. As a default, both the SD and microSD cards will operate in the faster SD mode unless configured to the slower SPI mode.

5. Practical Work "Mobile Node as a Data Logger (Using microSD card)"

The talk at the beginning of this paper dealt the concepts of the process of collecting and recording sensors data and the problems that exist especially in the cases of large or big data. In section 2, some of the used methods and techniques to collect data in both wireless and wired networks were presented and explained.

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With many attempts to efficiently, quickly and easily collecting data from network nodes, there are still a lot of shortcomings and obstacles. So we have been looking for new ways and means to collect sensors data and the choice was to use the SD memory card in all its specifications and capabilities that mentioned above (section-4). This type of storage media is the latest and most used in mobile devices such as mobile phones and cameras meanwhile they characterized miniature size and storage capacity up to 2TB (capacity of two or more hard disks).

Figure-4:
SD Card module

This practical part of this research demonstrates the design of a mobile data logger unit based on a microSD memory card. This mobile unit (or mobile node) will be used as a quick, easy, light and mobile tool to collect and save data from any places all over the proposed monitoring network [9]. Moreover, this mobile unit will be very useful where it will be self operated, self powering, and standalone monitoring unit (no need for additional components) that could be used at malfunction or disconnection of any network node. Obviously the mobile unit is not only mobile data logger but also a reserved network node (spare network node).

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5.1 SD Memory Card Format and File Naming

SD card Format- by formatting the card you will determine a required file system to read / write data to the card. Therefore we need a microSD card reader (adapter) and a computer to format the card. It is common that the SD card library provides both of FAT16 and FAT32 file systems, but using the FAT16 system is preferred. The process to format is fairly easy. But do not forget that the File Naming and the file systems have some limitations. Naming system must use the DOS format (DOS operating system), e.g. 8 digits for the name and 3 digits for the extension.

Figure-6: (a): SD card pins soldering

5.2 Microcontroller and SD card interfacing

As shown in figure-5 below the following diagram illustrates how to connect the SD card to the microcontroller breadboard which connected to three temperature sensors LM35 and one air quality sensor MQ-135 to collect and save these sensor readings [10]. The components required to run this experiment are:

- microcontroller
- breadboard
- Three LM85 sensors
- One air quality sensor
- MicroSD Card
- Power supply DC. 3.3V

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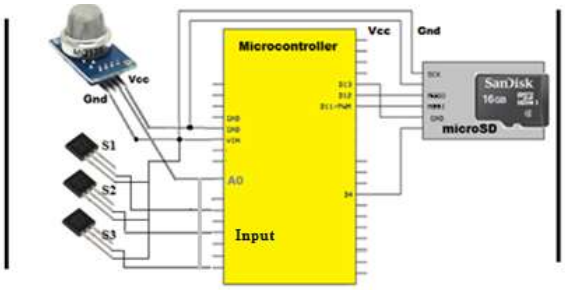
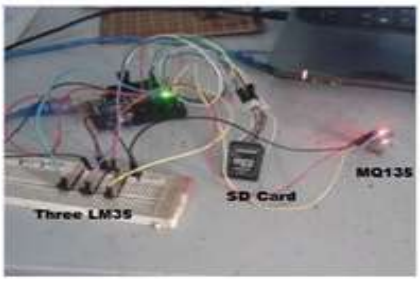


Figure-5: Microcontroller and microSD card interfacing

We may note that the SD card voltage values are differing according to the used SD card type. Also because of a lot of data transfer, SD cards will give the best performance when connected up to the hardware SPI interface pins on a microcontroller [11]. For 'classic or traditional' microcontrollers those pins are digital pins 13, 12 and 11. Also it needs a fourth pin (digital pin 4) for the 'chip/slave select' (CS or SS) line. The complete practical circuit is as shown in figure-6;



(b): SD card as mobile data Logger

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5.3 The Program Code of Mobile Data Logger

The program code is divided into two main parts or procedures, the first part is to identify and initialize the SD memory card (as shown in figure-7) to assure that the pin connections are right and the SD card is ready to work. The second part is to open a text file (with right file name) and to write the four sensors readings in that file. After writing the software code and uploading it on the microcontroller, the SD card well initialized and ready for data writing, the following information menu would be appear to display the SD card information.

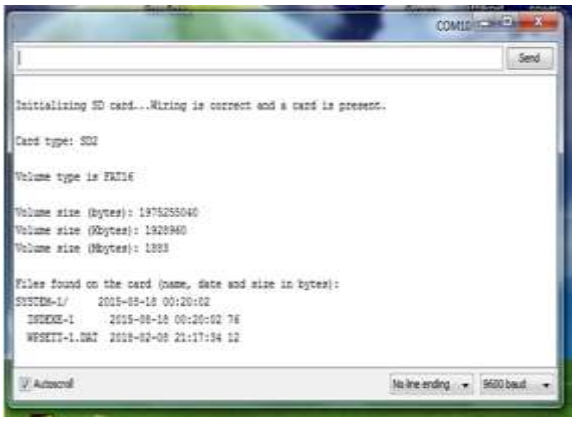

Figure-7: MicroSD card initialization

The following figure-8(a) illustrates the sensors (three LM35 and one MQ135) readings on the monitor while figure-8(b) illustrates or read these data from the stored file titled "DATALOG.txt" on the SD card.

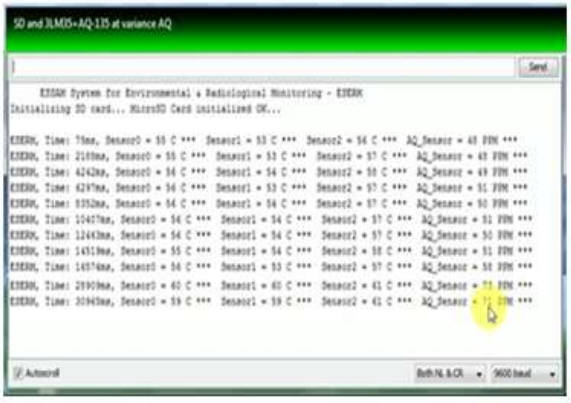

Figure-8 (a): Displaying Data of Data logger

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Figure-8 (b): Read data from the microSD memory card

Figure-9 illustrates the graph of these sensors values where the X-axis is the time in seconds and the Y-axis is the sensor values. There are 4 sensors and each of them was identified by a specific color (the air quality sensor is the orange).

As shown in the figure, the values of three temperature sensors are in range from 46 to 50 ^{o}C in normal state (area (1)) while the MQ135 reads value in range between 47 and 55 PPM (area (2)). When we burn a piece of paper besides the sensors, the sensors begun to read the higher temperature degrees (area (3)) and at the same time the MQ135 sensed higher air pollution at 100 second (area (6)).

At areas (4) and (5) the air quality sensor read high values due to the presence of a small amount of carbon dioxides gas meanwhile the temperature did not change. Finally after a short period of time, at 125 seconds, the overheat and CO2 effects were removed so the sensors came back to their initial state values (area (7)).

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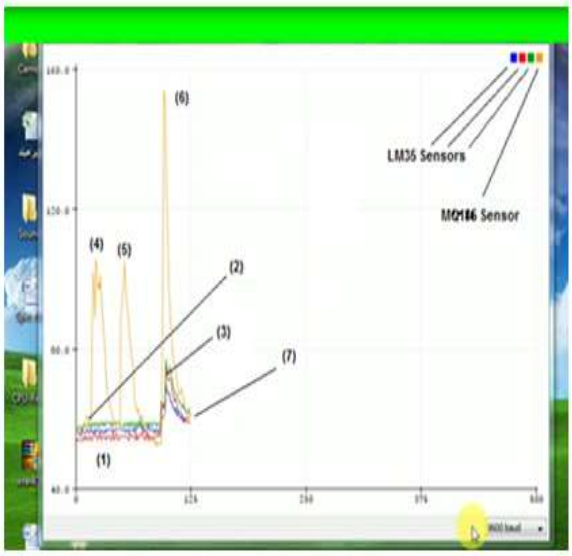

Figure-9 A Graph of Sensors Values

As shown in this practical experiment, the target was how to benefit from the great features and capabilities of the microSD memory card to build an effective mobile data logger to collect the network sensors data. Of course the miniature SD card was very ease and fast operation tool for sensor data logging/storing.

6. CONCLUSION

As an important part we discussed the difficulties / obstacles faced by both wireless networks and wired networks to collect the sensors readings. One of the most prominent of these problems was how to deal with large amounts of data or big data, which negatively affect the performance of data collection. So that the talk in this paper was to search for new or modern means of data collection and preservation to carry out the required data processing and analysis. In this regard, our research dealt with how to use the SD memory card as a quick, easy and effective way to collect data or sensor readings. Furthermore, we illustrated how to design a portable or mobile network node or unit to perform the required measurements of temperature (using three LM35 sensors) and air quality measurements (using MQ135 sensor).

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This portable unit, containing a Data Logger, can work independently and collect sensors readings and store them on a microSD memory card quickly and efficiently.

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