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Lightweight MySQL Connector/Library for Marvell MW300/302 and VADACTRO's eval-lit and its applications in IoT-based-WSN and machine learning ID3 algorithm

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Abstract— Wireless sensor network are playing key role in industrial and academic research. sensors of WSN provide lots of heterogeneous data that can be used for different IT, homes, offices, production facilities, and vehicles applications. Standardized formatted sensor data is useful for such applications. Programming WSN is difficult job. In this paper we have listed different types of sensors, wireless communication technologies and their applications that we have studied. We have proposed IoT-based-WSN scenario where smart Marvell MW302 and VADACTROs eval-kit will push sensor data directly into cloud database (here MySQL) without any intermediate server/hub and we have also analyzed the sensor data and monitored environmental condition. Based on these readings we prepared learning data-set on applied ID3 algorithm for predicting necessary condition for playing tennis.

I. INTRODUCTION

WIRELESS sensor network can be built by using low cost, fast hardware like Marvell MW302 and VADACTROs eval-kit, raspberry-pi etc. For building WSN we need some simple sensors and a eval-kit who is having GPIO capabilities and wireless capabilities. Many have worked on Marvell MW302 and VADACTROs eval-kit platform and implemented for measuring house temperature ,monitoring garden, use of occupancy sensor for tracking movement, monitoring the environment and its conditions using say gas sensors, building security system etc. Its not easy to build reliable WSN with other evaluation kits since the technology is currently evolving in IOT-based-WSN. For building a reliable and informative sensor network, we have worked on Marvell MW302 and VADACTRO's eval-kit. In this paper, we have discussed about WSN, sensors and their types, how WSN is part of IOT. For development we have used FreeRTOS as operating system on which Marvell SDK is there and using these os and sdk we have developed WSN scenario.

II. LITERATURE SURVEY

According to Parks Associates,

- The number of smartphones (excluding feature phones) worldwide is expected to top 1.1 billion in 2013. However, this is just the tip of the iceberg.
- Smart grid devices will reach 244 million;
- E-readers and tablets will be 487 million;
- networked office devices, 2.37 billion;
- Networked medical devices, 86 million;
- connected automobiles, 45 million;
- connected appliances, 547 million;
- connected military devices, 105 million;
- Information technology (IT) system devices, 431 million;
- connected supervisory control and data acquisition (SCADA)/industry automation devices, 45 million;
- And other connected consumer electronic devices minus smartphones, e-readers, and tablets will reach a whopping 5+ billion and counting.

In 2002, Greg Papadopoulos, Suns chief technology officer indicated that the first Internet wave consisted of an Internet of computers and the second wave, which we are currently in, is an Internet of Things that embed computers. The third Internet wave, which is an Internet of Things, consists of physical objects like thermostats, switches, packages, and clothes. The IoT will primarily expand communication from the 7 billion people around the world to the estimated 50 to 70 billion machines. This means significant opportunities for the telecom industry to develop new IoT subscribers that substantially surpass the number of current subscribers based on population. According to recent development analysis and prediction, by year 2020, we will have 16 billion connected devices, which will average out to six devices per person on earth. Devices like smartphones and M2M or thing-to-thing communication will be the main drivers for further development. M2M (machine-to-machine) refers to technologies that allow both wireless and wired devices to communicate with each other or, in most cases, a centralized server.

The History of sensor networks spans four phases:-

- Phase 1: Cold-war Era Military Sensor Networks during this period extensive acoustics networks were developed in United States for submarine surveillance.
- Phase 2:Defense Advanced Research Projects Agency Initiatives (DARPA 1980) Distributed sensor network(DSN) work aimed at determining newly developed TCP/IP protocols and ARPAnet's approach to communication could be used in the context of sensor networks.

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- Phase 3: Military applications Developed or Deployed in 1980's and 1990's. These were the first generation commercial products. Based on results of DARPA- DSN and testbeds developed, military planners set out to adapt sensor networks. For improved detection and tracking performance through the observations obtained from these sensor networks from different locations.
- Phase 4: Early 2000's Sensor Network Research, Due to the advancement in computing technology, communication technology, this is the second-generation commercial sensor network products era. For reliable and ubiquitous connectivity lot of research have been done and are currently going in 802.11a/b/g-based wireless networking and other wireless systems such as ZigBee, Bluetooth, WiMax etc.
- Phase 5: Third Generation (Late 2000's) In this generation size and weight of sensors are reduced. In is era sensors are developed using micro or nanotechnology. The node architecture is fully integrated sensing, processing and better communication. The protocol standards used are Wi-Fi,ZigBee, WiMax etc. Life span of these sensor networks is improved due to low power consuming devices.

Major challenges and hurdles in producing sensors and technology around them are -

- Functional capabilities
- Cost
- Size
- Power consumption
- Topology management complexity
- Scalability

Some experts predict that the IoT will help tackle two of the biggest problems facing mankind today: energy and healthcare. For handling lot of data which is made available by WSN's sensors we have proposed work in this paper in later section. In following tables we have highlighted rows where WSN will be playing key role.

We have also studied different technology standards which are the basic four pillars of IoT mentioned in below table.

Four Pillars of IoT				
Four pillars and Networks	Short range wireless	Long range wireless	Short range wired	Long range wired
RFID	YES	SOME	NO	SOME
WSN	YES	SOME	NO	SOME
M2M	SOME	YES	NO	SOME
SCADA	SOME	SOME	YES	YES

TABLE I

FOUR PILLARS OF IOT

RFID, WSN, M2M, SCADA are the basic but major pillars of IoT. We in VADACTRO have worked on home automation system and developed smart home switches (http://vadactro.org.in/index.php/products). Our next goal is to achieve sensor integration and data collection from different locations and analyze them for providing better service. Data collection from different locations and working area (heterogeneous) is helpful for developing context aware products.

The next TABLE: II we have listed application areas where sensor network can be deployed.

Application Areas		
Industry	Example Applications	Benefits
Medical	Wireless medical device	Remote patient Monitoring
Security	Home alarm and surveillance	Real-time remote security and surveillance
Utility	Smart metering	Energy, water, and gas conservation
Manufacturing	Industrial automation	Productivity and cost savings
Automotive	Tracking vehicles	Security against theft
Transport	Traffic systems	Traffic control for efficiency
Advertising and public messaging	Billboard	Remote management of advertising displays
Kiosk	Vending	Remote machine management for efficiency and cost savings
Telematics	Fleet management	Efficiency and cost savings
Payment systems	Mobile transaction terminals	Mobile vending and efficiency
Industrial automation	Over-the-air diagnosis and upgrades	Remote device management for time savings and reduced costs

TABLE IIAPPLICATION AREAS OF M2M

III. EXAMPLES OF SENSOR NETWORKS

There are different areas where these sensor networks can be used who can send or receive data from cloud or local database on another part of the network for processing and recording.

A. Automobile

In 21st century most of human expects vehicle to have smart sensors to perform smart operations like performance of engine, Tyre pressure, temperature inside engine and its subsystems, Anti-theft and tracking system for vehicle, many other company use industry standard interface called onboard diagnostics (OBD).

B.Environment

Examples of environment sensor networks are used to monitor air pollution, detect and track forest fires, detect landslides, provide earthquake early warnings, and provide industrial and structural monitoring.

C.Atmospheric

Atmospheric monitoring is closely related to environmental monitoring. Here more emphasis is given on atmosphere monitoring instead of whole environment. The obvious reason is that mammals simply can't survive without air.

D. Security

Security systems as sensor networks are those used for security and surveillance in home, offices, educational institutes etc.

IV. COMMUNICATION MEDIA

Communication media can be wired, wireless or hybrid.

A. Wired Networks

Wired networks can transmit data using wire or some type of communication wire like Ethernet wire. We have to add network hardware to the nodes in the sensor network.

B. Wireless Networks

In sensor network most popular is wireless sensor network. Here data is communicated using wireless technology such as WiFi, RFID etc. We require wireless router for wireless Ethernet (WiFi).

C. Hybrid Networks

It is the combination of both wired and wireless network. Each area may require a different form of sensor network. We can use wireless network where wired network is difficult to have.

V. SENSORS

We as a human can sense by observing (like light, gases, water vapor, and so on), feeling (like temperature, electricity, water, wind, and so on), and listening physical world. A sensor is a device that measures phenomena of the physical world. However, human can't see or feel things such as such as radiation, radio waves, voltage, and amperage. But by using sensors we can measure these things.

A. Accelerometers

For measuring motion and movement we need these kind of sensors. For sensing velocity, inclination, vibration etc. on several axes these sensors are designed.

B. Audio sensors

Microphones are used to measure sound. These kind of sensors mostly are analog, digital variants sensors are also there for better security and surveillance for higher compression of transmitted data.

C. Barcode readers

These sensors are designed to read barcodes. Most often, barcode readers generate digital data representing the numeric equivalent of a barcode. Such sensors are often used in inventory-tracking systems to track equipment through a plant or during transport.

D. RFID sensors

Radio frequency identification uses a passive device (sometimes called an RFID tag) to communicate data using radio frequencies through electromagnetic induction.

E. Biometric sensors

A sensor that reads fingerprints, irises, or palm prints contains a special sensor designed to recognize patterns.

F. Capacitive sensors

A special application of capacitive sensors, pulse sensors are designed to measure your pulse rate and typically use a fingertip for the sensing site. Special devices known as pulse oximeters.

G. Coin sensors

These devices are like the coin slots on a typical vending machine. They can be calibrated to sense when a certain size of coin is inserted.

H. Current sensors

These are designed to measure voltage and amperage. Some are designed to measure change, whereas others mea- sure load.

I. Flex/Force sensors

Resistance sensors measure flexes in a piece of material or the force or impact of pressure on the sensor. Flex sensors may be useful for measuring torsional effects or as a means to measure finger movements.

J. Gas sensors

Gas sensors measure potentially harmful gases such as LPG and methane and other gases such as hydrogen, oxygen etc. Other gas sensors are combined

K. Light sensors

Sensors that measure the intensity or lack of light are special types of resistors: light-dependent resistors (LDRs), sometimes called photo resistors or photocells.

L. Liquid-flow sensors

These sensors resemble valves and are placed in-line in plumbing systems. They measure the flow of liquid as it passes through. Basic flow sensors use a spinning wheel and a magnet to generate a Hall Effect (rapid ON/OFF sequences whose frequency equates to how much water has passed).

M. Liquid-level sensors

A special resistive solid-state device can be used to measure the relative height of a body of water. One example generates low resistance when the water level is high and higher resistance when the level is low.

N. Location sensors

Modern smartphones have GPS sensors for sensing location, and of course GPS devices use the GPS technology to help you navigate. Fortunately, GPS sensors are available in low- cost forms, enabling you to add location sensing to your sensor network. GPS sensors generate digital

data in the form of longitude and latitude, but some can also sense altitude.

O. Magnetic-stripe readers

These sensors read data from magnetic stripes (like that on a credit card) and return the digital form of the alphanumeric data (the actual strings).

P. Magnetometers

These sensors measure orientation via the strength of magnetic fields. A compass is a sensor for finding magnetic north. Some magnetometers offer multiple axes to allow even finer detection of magnetic fields.

Q. Proximity sensors

Often thought of as distance sensors, proximity sensors use infrared or sound waves to detect distance or the range to/from an object. Made popular by low-cost robotics kits, the Parallax Ultrasonic Sensor uses sound waves to measure distance by sensing the amount of time between pulse sent and pulse received (the echo). For approximate distance measuring, Its a simple math problem to convert the time to distance.

R. Radiation sensors

Among the more serious sensors are those that detect radiation. This can also be electromagnetic radiation (there are sensors for that too), but a Geiger counter uses radiation sensors to detect harmful ionizing. In fact, it's possible to build your very own Geiger counter using a sensor and a VADACTROs eval-kit (and a few electronic components).

S. Speed sensors

Similar to flow sensors, simple speed sensors like those found on many bicycles use a magnet and a reed switch to generate a Hall Effect. The frequency combined with the circumference of the wheel can be used to calculate speed and, over time, distance traveled. Yes, a bicycle computer is yet another example of a simple sensor network: the speed sensor on the wheel and fork provides the data for the monitor on your handlebars.

T. Switches and pushbuttons

These are the most basic of digital sensors used to detect if something is set (ON) or reset (OFF).

U. Tilt switches

These sensors can detect when a device is tilted one way or another. Although very simple, they can be useful for low-cost motion detection sensors. They are digital and are essentially switches.

V. Touch sensors

The touch-sensitive membranes formed into keypads, key-boards, pointing devices, and the like are an interesting form of sensor. You can use touch- sensitive devices like these for sensor networks that need to collect data from humans.

W. Video sensors

As mentioned previously, it's possible to obtain very small video sensors that use cameras and circuitry to capture images and transmit them as digital data.

X. Weather sensors

Sensors for temperature, barometric pressure, rain fall, humidity, wind speed, and so on are all classified as weather sensors. Most generate digital data and can be combined to create comprehensive environmental sensor networks.

VI. CURRENT RESEARCH AREAS

Project name	Research area	HTTP location
SensoNet	Transport, network, Data link, and physical layers. Power control, mobility, and task management planes.	http://www.ece.gatech.edu/ research/labs/bwn/
WINS	Distributed network And Internet access to sensors, controls, and processors.	http://www.janet.ucla. edu/WINS/
SPINS	Security protocol.	http://paris.cs.berkeley. edu/ perrig/projects.html
LEACH	Cluster formation Protocol.	http://nms.lcs.mit.edu /projects/leach
Dynamic Sensor Networks	Routing and power Aware sensor management. Network services API.	http://www.east.isi.edu /DIV10/dsn/
DataSpace	Distributed query processing.	http://www.cs.rutgers.edu /dataman/

TABLE III CURRENT RESEARCH AREAS

The physical layer is unexplored area in sensor network due to which there are many oprn research issues related to power-efficient transceiver design, modulation scheme etc. Modulation scheme can be baseband or passband. Hardware design has to be tiny, low-power, low-cost transceiver, sensing and excellent processing unit. Frequency of operation, predicting work load in processors are also important aspect to look into for efficient hardware design. Data collection and analysis is most relevant concept which helps use to un- derstand challenges and opportunities of data management in IOT. There are several concepts in IOT for data management where industry as well as academics are working together to find solution for following:

- Data Collection and Analysis
- Big Data
- Semantic Sensor Networking
- Virtual Sensors
- Complex Event Processing.

We have focused majorly on Data collection and a nalysis part.

VII. DATA COLLECTION AND ANALYSIS

This is one of the most important module for data man-agement. This model is constantly evolving so that it can support more features and provide more capacity to

external components. There are some more functions of data collection and analysis module.

- Customer data Storing, this data is provide by sensors
- User data and operation modeling, helps for creating new sensor data model and modeling of supported operations
- On demand data access, API for collecting sensor data whenever needed.
- Device event publish/subscribe/forwarding/notification: Collecting data in real time conditions.
- Customer rules/filtering: for correlating events customer/user can apply rules/filters.
- Customer task automation: Managing data automatically e.g. we have scheduler for sensor data collection and event triggering.
- Customer Workflow: User/Customer can customize their workflow according to their needs.

VIII. ENERGY ISSUES

In IOT, communication is most energy consuming task. So integration of on-chip communication module with processor is important to achieve communication in efficient way. Here in Marvell MW302 and VADACTRO's eval-kit they have integrated arm-cotexM4 with wifi module. There are many low power communication technologies:

Technology Standards						
	RFID	NFC	WiFi	ZigBee	Bluetooth	WSN
Network	PAN	PAN	LAN	LAN	PAN	PAN
Topology	P2P	P2P	star	Mesh, star, tree	star	Mesh, star
Power	Very Low	Very Low	Low-High	Very Low	Low	Very Low
Speed	400kbps	400kbps	11-10 Mbps	250Kbps	700Kbps	250kbps
Range (in meters)	upto 3	upto 0.1	100	30 - 100	upto 30	upto 200

TABLE IV
NETWORK STANDARDS AND THEIR PARAMETERS

IX. SENSOR INTEGRATION WITH MCU AND MYSQL INTEGRATION WITH SDK

We have used temperature and Humidity sensor (Keyes DHT11) for initial experiment.

Pin	Name	Description
1	DATA	Serial data output
2	VDD	Power supply 3 - 5.5 V DC
3	GND	Ground

TABLE V
PIN USE KEYES TEMPERATURE AND HUMIDITY SENSOR

DHT11 sends higher data bit first then lower bit data. Complete data size for transmission is 40 bit. The sent from sensor contains decimal and integral part. Data format: 8bit integral RH data + 8bit decimal RH data + 8bit integral T data + 8bit decimal T data + 8bit check sum. If the data

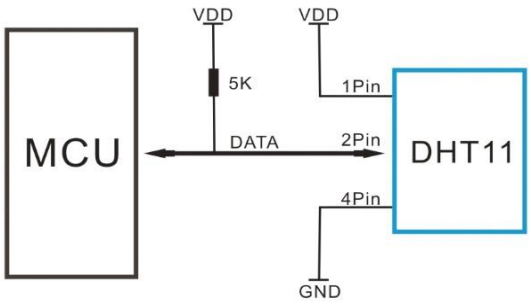

Fig. 1. Sensor connection with MCU.

Transmission is right, the check-sum should be the last 8bit of "8bit integral RH data + 8bit decimal RH data + 8bit integral T data + 8bit decimal T data".

A. Communication process

(Source: http://www.micropik.com/PDF/dht11.pdf) Data Single-bus free status is at high voltage level. When the communication between MCU and DHT11 begins, the programme of MCU will set Data Single-bus voltage level from high to low and this process must take at least 18ms to ensure DHTs detection of MCU's signal, then MCU will pull up voltage and wait 20-40us for DHTs response.

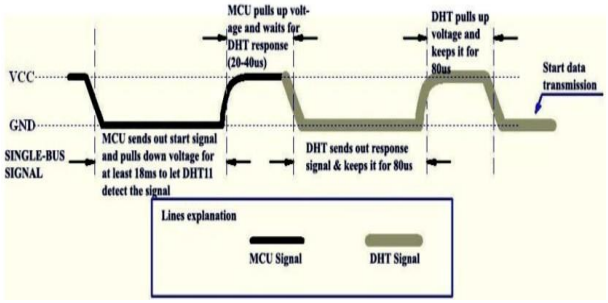

Fig. 2. MCU sends out Start signal and DHT response

DHT11 sends low-voltage-response signal to MCU, when it detects start signal, which lasts for eighty micro-seconds. After that DHT11 DATA Single-bus voltage from low level to high level and again it keeps for 80 micro-seconds for DHTs preparation for sending data. DHT11 sends response when DATA single-bus is at low voltage level. After sending response signal to MCU it goes to high voltage level and again it keeps it for 80 micro-seconds and now it is prepared for data transmission. When DHT is sending data to MCU, every bit of data begins with the 50us low-voltage-level and the length of the following high-voltage-level signal determines whether data bit is "0" or "1"

X. MCU SDK WITH MYSQL

Based on these above format we have integrated keyes temperature and humidity sensor with Marvell

MW302 and VADACTRO's eval-kit MCU's. We have taken readings and send them to cloud database (here

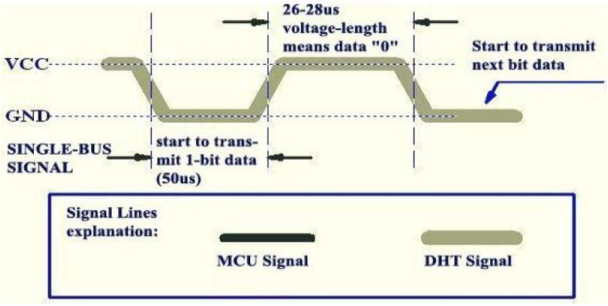

Fig. 3. Data "0" Indication

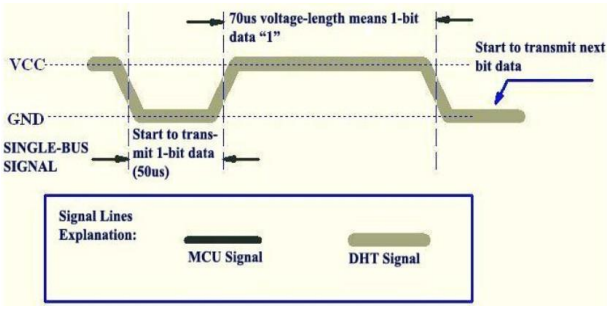

Fig. 4. Data "1" Indication

MySQL). For sending data we have used freeRTOS, Marvell SDK from which we are using LWIP functions to communicate between cloud database and MCU. For communicating with MySQL database on cloud, we have used internal documents of MySQL (source: https://dev.mysql.com/doc/internals/en/client-server-protocol.html) where client/server protocol is explained. We have send data packet by packet to MySQL cloud database. (Packet stucture for it is explained here: https://dev.mysql.com/doc/internals/en/mysql-packet.html)

These are the basic steps followed while programming MySQL Connector/library.

- Initial Handshake Packet;
- parse handshake packet;
- Authenticate; if successful then
- execute query; else
- Query syntax or semantic error or authentication failure

following diagram shows how handshakes are processed while processing packet between MySQL database and client

XI. Experimental results

We have taken several readings from sensor and pushed those readings to MySQL cloud database. Fig.6. shows the reading obtain"ts" is Time-stamp here,"temp" is temperature reading in Celsius and Humidity is in percentage.

In next figure: 7 Blue line indicates temperature in Celsius and red line indicates Humidity in percentage. The readings were taken on 25th April 2016. We started our experimental recording at 8AM and closed on 11PM. The overall temperature was mild, humidity was normal, outlook was sunny,

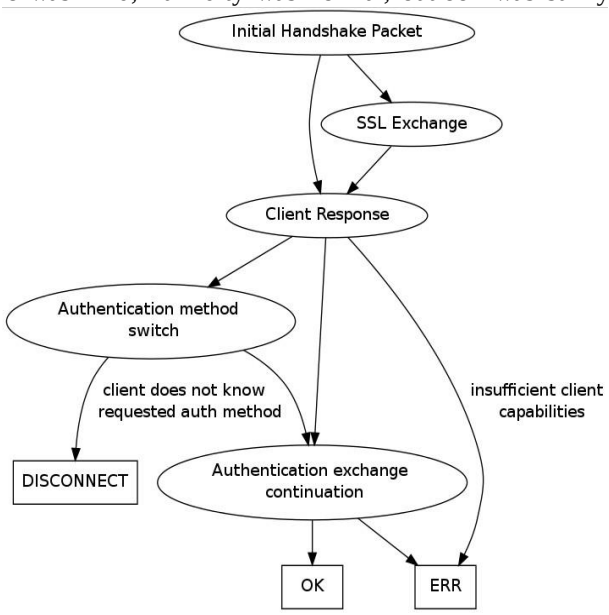

Fig. 5. Handshakes in MySQL packet processing

Wind was at slow speed. based on these readings we applied ID3 algorithm to make decision on "playing Tennis" example

Calculating entropy and gain based on the Table:VI

Learning set				
Outlook	Temp	Humidity	Wind	Play Tennis
Sunny	Hot(33)	High(85)	Weak	No
Sunny	Hot	High	Strong	No
Overcast	Mild(29)	High	Weak	Yes
Rain (12th may 2016)	Mild	High	Weak	Yes
Rain	Cool(22)	Normal (68)	Weak	Yes
Rain	Cool	Normal	Strong	No
Overcast	Cool	Normal	Strong	Yes
Sunny	Mild	High	Weak	No
Sunny	Cool	Normal	Weak	Yes
Rain	Mild	Normal	Weak	Yes
Sunny	Mild	Normal	Strong	Yes
Overcast	Mild	High	Strong	Yes
Overcast	Hot	Normal	Weak	Yes
Rain	Mild	High	Strong	No

TABLE VI

Network standards and their parameters

Gives:

Entropy ([9+, 5-]) = - (9 /14) log (9 /14) - (5 /14) log (5 /14) =0.940

Gain(Humidity) =0.151

Gain(S,Temp)=0.029

Gain(S, Outlook)= 0.246

Based on the above calculations attribute outlook is selected and algorithm is repeated recursively. The decision tree for the algorithm is shown in Figure 6.

Decision tree are commonly used for gaining information for the purpose of decision making. Decision tree starts with a root node on which it is for users to take actions. From this node, users split each node recursively according to decision tree learning algorithm. The final result is a decision tree in which each branch represents a possible scenario of decision and its outcome.

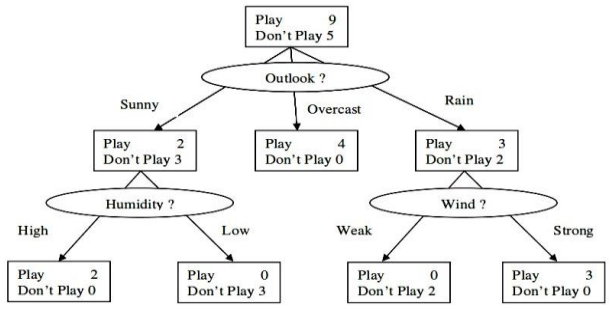

Fig. 6. Decision tree

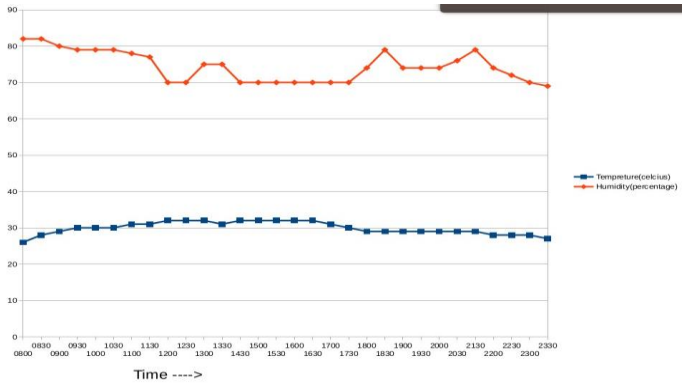

Fig. 7. Temperature and Humidity readings in a day

XII. CONCLUSION

Internet of Things (IoT) is not yet a tangible reality, but rather a prospective vision of a number of technologies that, combined together, could in the coming 5 to 15 years drastically modify the way our societies function. WSN will be playing key role in providing data from different areas around the world, they will become standard information tool throughout various industries. WSN integration with internet will provide us wide range of data. It is not entirely clear when these networks will become a fully functional, ubiquitous technology, but the progress in the direction of these networks is greatly important. In this paper we showed the implementation results of temperature and humidity sensor and how it is pushed into the cloud database (MySQL) using Marvell MW302 and VADACTRO's eval-kit. And based on these reading we were able to predict the possible outcomes for "playing tennis" example.

XIII. FUTURE PROPOSED WORK

We will be creating WSN using VADACTROs eval-kit over lager area. This eval-kit is having GPIOs for reading sensor data. The different sensor will make data directly available into cloud database server, in our case it will be MySQL. Making data entry directly into database and in particular table of cloud database without any intermediate server is challenging task. We are proposing to implement this for different sensors like flame sensor, accelerometer, Co2 sensor, Gas sensor etc. After successful integration of all sensors we will analyze environmental condition at particular position as well as we will apply different machine learning algorithms for analysis as well as training the system. An- other future proposed work is to make library open-source so that many enthusiast can use it for constructive purpose.

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