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Conference Paper · December 2017

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An Ad-Hoc Network based on Low cost Wi-Fi Device for IoT Device Communication

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***Abstract* - This paper provides an implementation which solves some of the problems in establishing and operation of ad Hoc networks for embedded system based IoT devices. For the implementation of the system, it used the currently famous module of ESP8266 ESP07 version and the module provides all the necessary features and facilities expected to be in such framework. The system also can work independently and it provides most of the operations that is not available in the current systems. This paper also shows one of the applications tested in this research as an implementation of the system. This solves most of the communication issues faced in ad hoc networks of various embedded systems.**

Keywords: Embedded Systems, IoT, Wireless networks, Ad Hoc networks, Esp8266, AES encryption, security

I INTRODUCTION

The ad hoc network can be an important part in IoT devices that is useful in communication. But in most researches rather than using the ad hoc networks most of them tend to use the basic network configuration where a wireless router based transmission is used [1]. The ad hoc based network is useful in places where low network coverage is given and places where a wireless router specifically do not need to be installed just for one or two sensors. When considering about IoT devices most of them are embedded systems [7]. The use of ESP8266 has been wide spread due to low cost and higher support for embedded system and also can act as a stand-alone microcontroller but one problem is that, this device does not have many ad hoc network based implementations. In this paper we are going to address this issue and implement an ad hoc network based device using ESP8266 that operates in the application layer.

II THE NEED OF THE SYSTEM

The ad hoc networks are not relatively new to the networking area as this has been used and applied for several years but to the embedded systems this is relatively new as not many researches have been engaged in this problem domain as most sensor arrays and stand-alone IoT devices tend to cluster around a given wireless router or an access point but this is relatively costly as if only one or two IoT devices are in the vicinity and if the given sensor array spreads a vast area this forces the designers to use many access points around the area to communicate [1, 5, 6, 8, 13].

The ESP8266 has been used to many embedded systems due to the cost effectiveness and the higher support given by the developer community not only this has been used as a supporting device to the embedded systems this can act as an embedded system alone this can cut the cost for additional devices as well but the problem is that the devices still cannot stand as a device that can stand alone and communicate wirelessly to establish a network for their own purposes this paper tend to solve this problem by introducing an ad hoc network implementation to the ESP8266 modules [2,4].

One of the problems faces is using the IoT networks in urban areas and fixing access points around the area this can be solved using the ad hoc networks. Another basic problem that have been faced is in most that for harsh environments like mines the networks have to be there but the problem is creating new access points daily and networking inside these types of environments or tunnels so use of the ad hoc networks will solve this problem [2 ,14].

So the need of this kind of device is critical in many situations

- To communicate in harsh environments with no proper network coverage.
- To implement an IoT system which has no clear cut network structure.
- An ad hoc system which can store vast amount of data and send them all when the connection is established to the server.
- Provide the security for the data gathered and send in the network.
- Provide a versatile platform which enables to add sensors easily and create custom made IoT devices according to the user's needs.
- Provide low cost versatile networking solution for the IoT devices.

III RELATED WORK

There are some work related to this area but not directly associated with the ad hoc network.one of the most popular implementation is the easyMesh by a developer called coopdis in git hub according to the implementation he has done the mesh is created by the code and manage by itself and the communication is based by the chip ID in each

ESP8266 device [10]. This do not need the support of a router to keep the network functioning properly as well. This creates the basic essentials of the network fulfilled. But there are some problems in this integration [10].

- This is directly build for the Arduino platform
- The number of devices each node support is limited
- The security levels of the communication is node defined
- The connection to the internet and publishing the needed data to the Internet is not given.

Another famous implementation is the nodeMCU based system which incorporates the GUI based developing platform to create a mesh network this also fulfils the basic needs of the ad hoc network but do not give fulfil the following needs.

- Directly designed to address nodeMCU based environments
- The number of devices connected is limited
- The security levels of the communication is not defined
- The connection to the internet and publishing data is not defined

So to address the above mentioned problems and create a protocol that can standalone and manage the network and fulfil the given needs is done by this paper. The device that is proposed can be used to implement ad hoc network using ESP8266 module.

So by analyzing the above implementations we can see some problems in the existing systems.

- No standard method of communication
- No standard device is used in communication
- The Memory capacity of the nodes are not strong enough
- The user has to implement complex control mechanisms to network the devices
- The platforms that are supported is limited and each platform has unique way of configuring than a generalized method
- The cost of the system may vary according to additional devices used
- No clear security methods used

This device is proposed to avoid the problems given above.

IV IMPLEMENTATION

The device proposed could achieve the given criteria.

- Create ad hoc network and manage by itself without using a router
- The adoption of basic security
- The storage of data for long time in each node
- Post data when the internet connection is available

This device has different steps and modules.

- The connection of the node to the network
- Storing the data needed
- Sending the data needed to the internet based server
- Securing the data transfer
- Interface for the operations

The main communication module used in this device is the ESP8266 [9]. Which is a popular device used in IoT based systems. Here the ESP07 version is used for this purpose as there are IO pins for the SPI communication. Another module that is used is the SD card module and a 3.3v power module.

Fig.1 The ESP8266 ESP07 module

The total system can be shown by a simple block diagram.

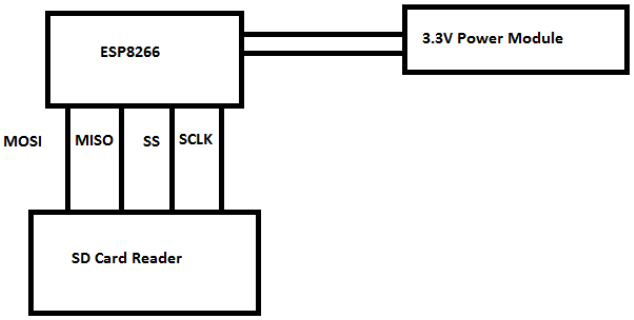

Fig.2 the System Block Diagram

A The Connection Of The Node To The Network

The connection of the node to the network can be done in many steps.

- If there is no available other nodes

    - Create a WiFi access point with a given label
    - Create a Server with a given port
- If there is available nodes
    - Connect to all access points available in the given label
    - Connect to all the servers available in the access points and send the MAC address
    - The servers should register MAC address as a nearby node and this massage is send by the Node continuously to other access points within a given time interval
    - Create a WiFi access point with a given label
    - Create a Server with a given port
- If new node is available with given access point label
    - Do action that is done if there are available nodes

B Storing The Data Needed

The storing of the data can be done in a formatted text which is encrypted by the current nodes passwords.

The format of the file can be given as

<The Node MAC Address>

<Data Received>

As the data in the file is encrypted an attacker cannot read the content stored in the SD card. The files are encrypted in the AES algorithm.

C Sending the data needed to the internet based server

When there is no available router with internet connection the Node will send the data to all the adjacent Nodes to save the data with its MAC address in the SD card

When a router with internet connection is available to the wireless network with a given label. The nodes in the vicinity will send others a request to connect and send data the one with smallest MAC address is allowed to connect to the Router and send the data as a bulk to the server given.

D Securing The Data Transfer

The transfer of data is done using the help of the AES encryption where the necessary security feature is added to the communication. Here the Arduino has a built in library to supply the AES encryption. The library name is Arduino AESlib [11]. The security key can be inserted into the device at the configuration. This key is different from the file encryption key.

E Interface For The Operations

E.1 Serial Communication

The operations needed for the device is handled through serial interface of the device so any device that is connected to the device through serial communication can set the parameters by sending the data trough serial interface. The necessary configuration details are stored in SD card as a file and encrypted. The file encryption key is the only key stored in the device and it is stored in the ROM of the device.

The Serial interface allows to set the following parameters

- AES Key for the file encryption
- AES Key for the network communication
- The Ad Hoc network Name Label
- The Wireless Router Name Label
- The Serial Transfer Rate
- The data to be sent

E.2 The Device In Built I/O

The devices in built I/O device can be used to connect the other sensors so there is no need for connecting additional microcontrollers. The ESP07 itself supports for one ADC and three GPIO pins and the GPIO pins can be used as I2C where software I2C can be used [9, 12].

V APPLICATION BASED ON THE DEVICE

A Application for Environmental Pollution Monitoring System for Urban Areas

The application proposed is an IoT device that can be used in the cities to monitor their CO levels. The gas sensors used here is MQ7 gas sensor this has a 5V heater coil and a load is used to get the Analog Voltage value to the devices ADC pin. By measuring the value received to the ADC the value with a time stamp provided by the RTC which is connected through I2C connection.

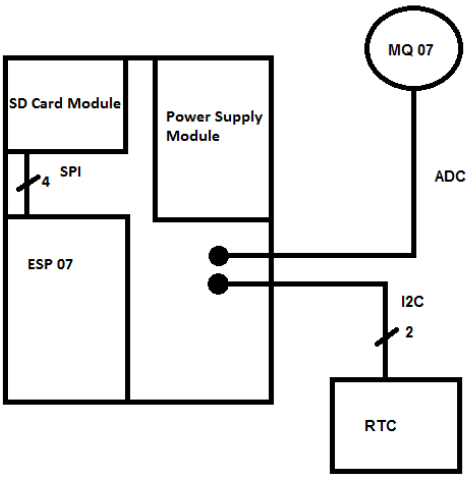

Fig.3 the Air Pollution Monitoring System

Before the device is fixed to a position we send the,

- AES Key for the file encryption
- AES Key for the network communication
- The Ad Hoc network Name Label
- The Wireless Router Name Label

Through the serial communication interface of the device. Then the device is fixed to the given position.

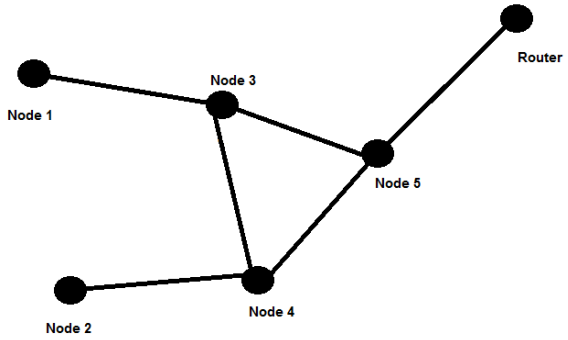

Fig.4 The Air Pollution Monitoring System Ad Hoc Network

After the network has been established the nodes communicate each other and send each of their data to the central server through the router.

B Application for Detect Harmful Gases in Mines

In mines there are some harmful gases to human to detect these gases and predicted a device can be made with this device. Where the gas sensor is connected to this device through ADC and then setup a network as in a mine a permanent network cannot be made and there is a harsh environment.

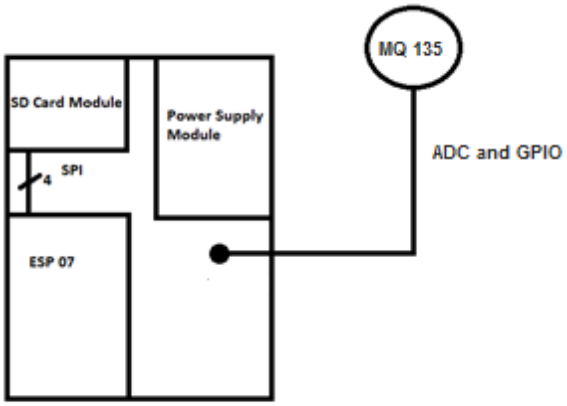

Fig.5 The Mine Gas Detector

So this device can be used their. To measure the concentration of the Gas we can use MQ 135 gas sensor.

Before the device is fixed to a position we send the,

- AES Key for the file encryption
- AES Key for the network communication
- The Ad Hoc network Name Label
- The Wireless Router Name Label

Through the serial communication interface of the device. Then the device is fixed to the given position.

By Keeping track of the MAC address of the Device the measurements of the gas levels can be monitored.

C Rainfall Monitoring system to jungles

There are systems to measure the rainfall using the sensors and send data by SMS these cost much for the environments like jungles as there are many nodes in the jungle.

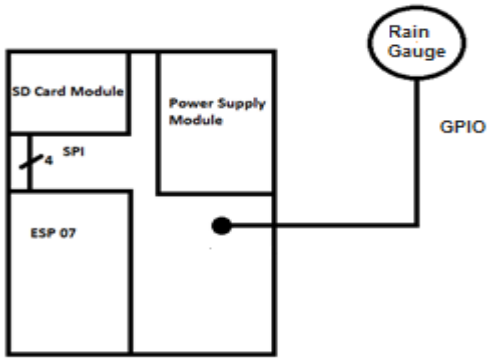

Fig.6 The Rainfall Monitoring device

This device is using a Rain Gauge and due to using of the ad hoc network the need of access points is not needed.

Before the device is fixed to a position we send the,

- AES Key for the file encryption
- AES Key for the network communication
- The Ad Hoc network Name Label
- The Wireless Router Name Label

Through the serial communication interface of the device. Then the device is fixed to the given position.

So this device provides a structure that other existing systems do not provide readily like,

- Easy to establish network only have to give the name
- Reduce the cost for routers as they communicate their own
- Have a big inbuilt memory to store data until transmission than other devices
- Has a security to the data transmitted and stored
- Can be also used as a microcontroller for general purposes

VI EVALUATION

The system is evaluated alongside with an Arduino based ESP module with ad hoc network. The Arduino based network can only store very limited number of data set compared to the device. This has been simulated for some number of data set which is a string of 100 characters run through a loop between two nodes and calculated through the number of lines in each file where the data is stored.

TABLE 1
The Testing On Data Storage

No of data sets($x10^3$) approx.	Arduino based network($x10^3$) approx.	Device based network($x10^3$) approx.
10	5	9
15	6	15
20	5	20
25	6	24
30	6	29
35	4	35

When the data is monitored through wireshark the Arduino based nodes data transmission can be seen through plain text while in the device based transmission messages are encrypted.

VII FURTHER WORK

The device that is developed can be used into many ad hoc network applications but to improve this model there are many things that have to be included

- A method to insert program or a flow of the program easily to device through serial interface.
- Attach a GPRS module to the device so that use of the routers can be eliminated through introducing one device with GPRS to the ad hoc network.

VIII CONCLUSION

The device that is proposed can provide the following services that is lack for today's implementations for the Ad Hoc networking for embedded systems.

- The network security
- High data retaining ability for the nodes that has problems with internet connection
- The IoT capabilities where connecting to the internet is a must in operation.
- The internal networking and operations are hidden from the user to easily work on other matters of the design

So this device is good for using in different terrains where a network is difficult to establish.

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