DNAIoT - Dynamic Network Architecture for IoT

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Abstract — Cyber-physical systems consist of various domains such as sensing, computation, controlling and networking in infrastructure, often connected by the internet. Controlling each device with separate controllers or switches seems tedious and troublesome. In today's world, smart devices or an intelligent hub allow us to connect a limited number of devices, usually around 30-40. In this paper, we propose a way in which you can connect to over 200 IoT devices seamlessly without affecting the bandwidth to a single point. In a connected network system, you can increase the number of devices linearly. It is a unique system that is different from the existing systems based on WiFi and Bluetooth. We have used WiFi as the first communication link, and for controlling the IoT devices, we are using the Arduino Uno WiFi REV2 microcontroller equipped with Zigbee[2] communication. The Arduino Uno WiFi REV2 works as a bridge between WiFi and Zigbee[2] communication. This is a simple IoT-based work that connects multiple devices at once and provides a stable, reliable and fast connection, communication, and control between the devices As per our methodology we can connect more than 2000 devices over a range of 1000 meters.

Keywords: Internet of Things, Embedded systems, Zigbee, WiFi, Smart devices.

I. INTRODUCTION

A CPS or Cyber-Physical System is an intelligent computer system that monitors and controls physical devices by human-created computer algorithms. CPS is a class of embedded systems that incorporates engineered computing and communicating systems in hardware and software elements. It is the base for developing intelligent buildings or smart homes, intelligent gadgets, new innovative medicines, etc. CPS is used in numerous fields such as SHM (Structural Health Monitoring), flight test instrumentation, networking systems, energy systems, and environment monitoring.

Our system integrates wireless technologies, namely WiFi and Zigbee[2], since cyber-physical systems involve the integration of cyber and physical components. This project also consists of using microcontrollers and ethernet shields which are embedded systems. When we think of a traditional system built for this purpose, such as Multinet [1], even though it enables increased range and better connectivity for end-users, it is limited by the surge in power usage, which also comes at an exorbitant price point. For a Wifi based system that uses communication and network protocol based on IoT, there are issues regarding range and speed when more devices are connected.

In case of WiFi, we are moving ahead with the assumption that our router is one of the best available in the market, the "Asus GT-AX11000 ROG Rapture Router (Black) AX11000 " [6] which is compatible with most IoT devices and has long-range connectivity[8]. All data provided below will be based on our WiFi and Zigbee[2] connectivity findings.

II. RELATED WORK

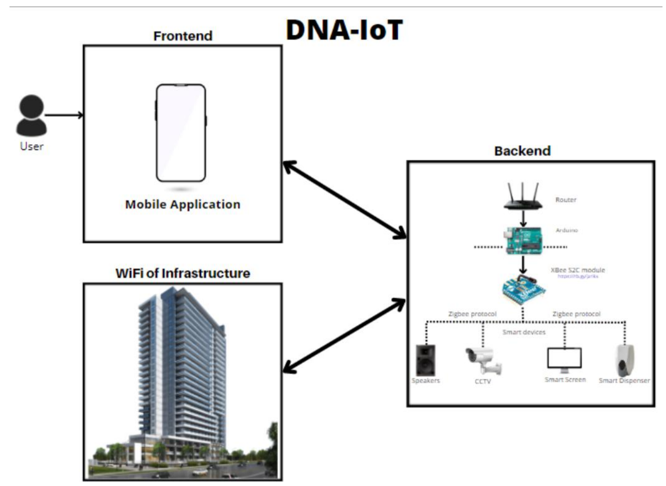
1. In the paper titled "MultiNet: Connecting to Multiple IEEE 829.11 Networks Using a Single Wireless Card" by Ranveer Chandra(mail - *ranveer@cs.cornell.edu*), Paramvir Bahl (mail - *bahl@microsoft.com*), Pradeep Bahl(mail - *pradeepb@microsoft.com*) They describe a new architecture and algorithms.
2. The documentation titled: "Digi XBee S2C 802.15.4 RF Modules" includes the documented official data regarding the module we have used in our prototype. XBee S2C module enables the prototype to possess Zigbee technology. These modules are inexpensive and effortless to deploy. It provides scathing connectivity to sensors and devices.
3. In the documentation titled: "Arduino Uno WiFi REV2", This documentation consists of the microcontroller "Arduino Uno WiFi REV2" information. It houses the ATmega328p microprocessor. It is mainly used in the construction of embedded electronics.
4. In the paper titled "Study on Zigbee Technology" by Muthu Ramya.C (mail - ramyacece@yahoo.co.in), Shanmugaraj.M (innoraj@gmail.com) and Prabakaran.R (mail - hiprabakaran@gmail.com). These researchers have studied wireless sensor networks. Zigbee is a wireless technology that uses the services of IEEE 802.15.4. These networks have numerous benefits over other networks, which has been the main topic of research in this paper. It includes the applications and in-depth explanation of Zigbee technology maintained by the Zigbee alliance.
5. The paper titled "Network Architecture and Security Issues in Campus Networks" by Mohammed Nadir Bin Ali (it@daffodilvarsity.edu.bd) and Prof. Dr. M. Lutfar Rahman (aktarhossain@daffodilvarsity.edu.bd) discusses about the network architecture of smart devices and Wi-Fi used in university campuses and its security issues as the autonomous networks used, stores data vital to the institution.
6. In the paper titled "Research on the architecture of Internet of Things" by Huiying Du defines the currently accepted three-layer structure of the Internet of Things. SInce it can't express the whole features and connotations, they introduce a new five-layer architecture business layer, application layer, processing layer, Transport layer, and perception layer.
7. This paper talks about short-range network connectivity solutions such as Zigbee[2], WiFi, etc. It details the effect on factors such as the range and number of devices connected in short-range networking protocols.

III. Methodology

A. Working

Among the components listed above, the WiFi router is the base point from which all communication is linked. The Arduino Uno WiFi REV2 acts as an interface between the WiFi and the XBeeS2C shield. The XBeeS2C is our Zigbee[2] access point which encompasses all the other IoT devices in the system. A smartphone is used as a controller device that is connected to the WiFi network of the router.

The WiFi router is connected to the network system of the infrastructure. The network system of an infrastructure consists of routers, hubs, switches arranged along a specific topology, such as mesh, star etc. For our purpose, we'll be using a WiFi router per floor of the building to act as a base point through which we will be connecting to all other devices. An Arduino Uno WiFi REV2 will be used as an access point for the zigbee module. In DNAIoT we are using a XBee S2C module to achieve Zigbee Communication. The module can connect to all the IoT devices via Zigbee. Upon successful connection all the devices will be linked to our Arduino Uno WiFi REV2. The Arduino Uno WiFi REV2 is connected to the base point, which is the WiFi router. A control device is connected to the WiFi router. This control device communicates with the Arduino Uno WiFi REV2 over the WiFi connection and helps us in turn send and receive information to all the IoT devices connected. This provides us with a higher range of access, a single point of access and eliminates the need for multiple routers for more than 200 IoT devices.



[10]DNAIoT

B. Components List

- Arduino Uno WiFi REV2: This is a microcontroller that is based on a package ATMEGA480. The board is issued with 14 digital input/output pins and 6 analogue inputs. Using this chip we can

connect to a WiFi network securely using its ECC608 crypto chip accelerator.
- XbeeS2C shield: This shield is used in this abstract to allow the microcontroller to add wireless capabilities to the prototype. It integrates directly with any development board that has the same trace as any Arduino Uno WiFi REV2 board.
- A power bank: This component provides us with the DC power supply required by the prototype (5000 mAh).
- WiFi Router: This device serves as an access point in our network and connects the User to the Arduino Uno WiFi REV2 boards, the users serving as a gateway between them. It also connects to the controller (or smartphone) in this scenario.

IV. *ANALYSIS OF THE RESULT*

Following the architecture diagram[10] we analyze factors such as range and number of devices connected in this section.

A. *Number of Devices Connected*

- Our WiFi router can connect with up to 10 Arduino Uno WiFi REV2s alongside a smartphone without any observation of reduction in bandwidth.
- The Arduino Uno WiFi REV2 connects to the XBeeS2C[2] shield which in turn can handle up to 250 devices.
- So, 10*250 = 2500 IoT Devices can be connected at any given time.

B. *Range*

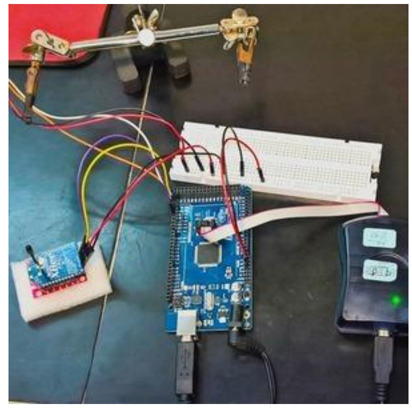
As per our theoretical calculations:

- WiFi → 40m (ideally*)
- XBee Module → 100m (ideally**)
- As per our architecture diagram; Arduino Uno WiFi REV2 is connected to WiFi and on one router we can connect up to 10 Arduino Uno WiFi REV2s before observing the bandwidth limitations.
- (WiFi router → tested with 10 Arduino Uno WiFi REV2 with 30Mbps speed on 2.4 GHz bandwidth)
- The 10 Arduino Uno WiFi REV2s in turn are connected to 10XBee modules and considering the Arduino Uno WiFi REV2s are in the extent of the circle. We have a combined range of
- 40m(WiFi) + (10*100) = 1000 + 40 = 1040 metres
- A coverage of 1040m in terms of IoT devices.

*values obtained from Router details of (Asus GT-AX11000 ROG Rapture Router (Black) AX11000)

**values obtained from Xbee S2C point.

V. *VALIDATION*



[11]

The setup we have here[11] is replicating the architecture diagram[10] we have proposed above. In this case we have established Zigbee[2] Communication to another zigbee module. In this scenario, we observe that the range offered by Zigbee[2] communication is around 90-100 meters. The connection strength was stable at 90 meter range with no drops in connection. In our testing we were able to connect more than 100 devices through this method.

This scales up to 240 IoT devices per XBeeS2C[2] module.

In case of WiFi only systems, it is limited to only 32 devices per WiFi router, within a range of 25 meters. This solution is expensive when considering the area covered by large infrastructure such as malls, universities etc. Automation of large scale buildings would be costly and would require multiple access points to connect to each and every device.

VI. *RESULT*

To evaluate the performance of our system, we have used theoretical values adjusted to 5% deflection in numerical values to match practical usage. From our validation technique, we achieve the connection to a range of 95 Meters without any drops in connection. In terms of number of devices, we are able to connect to a higher number of IoT devices which can be scaled exponentially depending on the number of Arduino Uno WiFi REV2 we use for a network system. This is a much better result compared to WiFi-only network systems.

VII. CONCLUSION

In the Cyber Physical systems domain, there have always been issues when it comes to achieving a stable network connection and managing all the connected devices over existing network architectures. In DNAIoT we improve in terms of Range, Number of devices that can be connected and offer a comparatively cheaper solution to achieve the goal of automation on a large scale.

REFERENCES

[1] Ranveer Chandra, Paramvir Bahl and Pradeep Bahl. "MultiNet: Connecting to Multiple IEEE 802.11 Networks Using a Single Wireless Card" https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/multinet_infocom.pdf

[2] Digi International Inc. "DIGI XBEE S2C 802.15.4 RF MODULES" https://www.digi.com/resources/library/data-sheets/ds_xbee-s2c-802-15-4

[3] Arduino. "Arduino Uno WiFi REV2" store.arduino.cc/products/arduino-uno-wifi-rev2

[4] Muthu Ramya.C, Shanmugaraj.M and Prabakaran.R. "STUDY ON ZIGBEE TECHNOLOGY" https://www.researchgate.net/publication/261497749_Study_on_ZigBee_technology

[5] Vishwas K V, Abhishek V Tatachar, Shivanee Kondur, Amith R, Varun Y C, Dr.Kiran Y C. "Zigbee, It's Applications and Comparison with Other Short Range Network Technologies" https://www.researchgate.net/publication/352935731_Zigbee_It%27s_Applications_and_Comparison_with_Other_Short_Range_Network_Technologies

[6] ASUS GT-AX11000 ROG Rapture Router AX11000 https://rog.asus.com/in/networking/rog-rapture-gt-ax11000-model/

[7] WiFi range statistics https://www.lifewire.com/range-of-typical-wifi-network-816564#:~:text=A%20general%20rule %20of%20thumb,indoors%20and%20300%20feet%20outdoors

[8] .Zigbee Range Statistics Zigbee Protocol - an overview | ScienceDirect Topics

[9] A study paper on Vision of IoT by Manikandan L C https://www.researchgate.net/publication/347091693_A_Study_Paper_on_Vision_of_IO

[10] DNAIoT Architecture Diagram

[11] Physical setup of the proposed Architecture Diagram

[12] Network Architecture and Security Issues in Campus Networks. (PDF) Network architecture and security issues in campus networks

[13] Research on the architecture of Internet of Things. (PDF) Research on the architecture of Internet of Things