PhD Proposal

PhD. Research Proposal
University of Gloucestershire
PhD Cyber & Technical Computing

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Working Title:

Can the Internet of Things (IoT) be used to monitor and record levels of radiation and meteorological factors within the Chernobyl Exclusion Zone (CEZ).

Introduction:

I am writing this proposal to support my application to the university and my chosen supervisor to study for the award of Doctor of Philosophy (PhD) in computer science or creative computing to study specifically the topic of the Internet of Things (IoT), I have also been thoroughly interested in the 1986 incident when No.4 reactor at the Chernobyl Nuclear Power Plant (ChNPP) exploded.

Literature Review:

Chernobyl

The Chernobyl Incident

Radiation Monitoring

Internet of Things IoT

IoT Environmental Monitoring

IoT Radiation Monitoring

IoT Radiation & Environment Monitoring

Knowledge Gap:

Questions:

1. Do meteorological factors influence the radiation emissions within the Chernobyl Exclusion Zone?

2. Do variations of wind move radioactive particles around the zone, or are they too far leached into the ground after 40 years of exposure to the elements?

3. Can an Arduino based Wireless Network be deployed in the Chernobyl Exclusion Zone collect Radiation data over a full 12-month period?

4. At what strength/dose of concentrated radiation does an Arduino cease to function correctly?

5. What suitable materials can be used to protect the Arduino Wireless Sensor Network when deployed within the Chernobyl Exclusions Zone (CEZ)?

6. How long does it take for an Arduino to cease functioning correctly when subjected to a source of concentrated radiation?

7. At what heat temperature will an Arduino cease to function correctly?

8. At what cold temperature will an Arduino cease to function correctly?

9. What type of Wireless Communication modules associated with Arduino can be used to transmit and receive data over the longest distance using the least amount of power?

10. Will increasing the voltage supplied to the Tx/Rx units increase the range/distance that the modules can operate at?

11. Do extremes of weather reduce the distance/range the Tx/Rx module can Tx/Rx data?

12. What is the largest data packet size that can be sent and received over the wireless network?

13. Do levels of radiation within the zone interfere with the transmission and receiving of data packets?

14. Are the levels of radiation within the zone too intense for the deployment and operation of the Arduino Wireless Sensor Network (AWSN)?

15. Will the Arduino Wireless Sensor Network (AWSN) survive the full 12-months of data acquisition within the zone.

16. Since the Russian invasion of Ukraine in March 2022, how much radiation has been disturbed and stirred up with the movement of troops and vehicles within the zone.

17. Can the Arduino Wireless Sensor Network (AWSN) identify specific hot spots or locations with increased activity?

18. What method is best for supplying power to the Arduino and associated sensors whilst deployed within the Chernobyl Exclusion Zone?

19. How far have levels of radiation dropped within the zone since 1986?

Methodology:

1. **Background reading & research around Chernobyl 1986**

   I will Undertake deeper reading and research around the incident that destroyed the reactor at the Chernobyl Nuclear Power Plant (ChNPP), this will include the reading of current publications (Books, Journals, Research papers by other institutions, approaching government agencies both the UK and international, identify information that may previously have been overlooked or not published.

   I will research around the following topics associated to the Chernobyl Incident (No particular order):

History of Chernobyl	Build up to the Explosion	Sarcophagus
Liquidators	Pripyat Town	New Safe Confinement
RBMK Reactor	Iodine 137	Corium
Strontium	The Kremlin	Chernobyl Divers
Skala Computer System	Generator Run Down	Az-5 / A3-5
Soviet Party	Radioactive Cloud	Uranium 235 ^{235}U
Robots	Notable People	Firefighters
Life in the Zone	Chernobyl Stalkers	Wildlife in the Zone

Table 1: *List of items for Background Reading*

2. **Commercial of the Shelf (COTS) transmission (Tx) and Receiving (Rx) modules range/distance investigation.**

   I will acquire a variety of different transmission and receiving modules that can be connected to the Arduino platform to send and receive data wirelessly and investigate the longest distance they can operate at, this will include testing overland over different terrain, in different weather conditions.

   I will conduct a number of tests utilizing a variety of different wireless communication modules suitable for the Arduino platform to send signals/data packets between Arduino platforms and ascertain their total operating range over a variety of different environments and in a wide variety of weather conditions, the British Isles can certainly provide the terrain and weather conditions.

3. **GPS Module Accuracy Investigation**

   I will acquire a variety of GPS modules that can be coded to the Arduino platform to ascertain their accuracy to give precise Latitude and Longitude coordinates, this will be of most importance when it comes to my field research project in year 3 of my degree.

   I will test a variety of different GPS modules that can be connected to the Arduino platform and ascertain the GPS modules accuracy in relation to a standard GPS module (Garmin handheld device) and also a mobile phone GPS mapping software. This will be vital to collecting location data from each Sensor node when they are deployed within the Zone.

4. **Arduino Radiation Tolerance Investigation**

   I will acquire time on the Gamma Irradiator equipment at the Henry Royce Institute (HRI) at the National Nuclear Laboratory to use their F812 Gamma Irradiator, which contains a source of radiation (Cobalt 60 ^{60}Co), and investigate at what point the Arduinos will cease to function correctly once they have been irradiated.

   This was a major investigation component for my Master's dissertation, however, Covid-19 put the country into lockdown, and I was therefore not able to physically conduct this experiment.

   I will subject a number of Arduinos to a source of concentrated radiation within the Gamma Irradiator starting with a low dose rate and short amount of time, after each stage of testing the Arduinos, the dose rate and time will be increased. I know I can irradiate at a minimum of 5 Grays/Min up to 450 Grays/Min inside the chamber. Obviously the higher the does rate per minute the quicker the Arduinos will suffer Radiation-Induced Damage (RID).

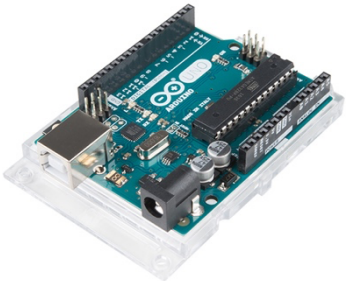

Figure 1: *Arduino Uno R3*

Arduino. (2022). *Arduino Uno R3.* Available: https://docs.arduino.cc/hardware/uno-rev3. Last accessed 18th March 2022.

Figure 2: *F812 Gamma Irradiator Chamber*

Figure 3: *Gamma Irradiator Control Panel*

The Lunokhod STR1 Rovers that were put on the roof of the damage reactor lasted for 63 Days **[#]**, and the Yellow "Joker" Robot that was supplied by German Police lasted minutes due to the astronomically high levels of radiation and a piece of debris getting lodged in the tracks **[#]**.

Paul. (Unknown). *Buriakivka – radioactive waste facility.* Available: http://www.chernobylgallery.com/galleries/buriakivka-radioactive-waste-disposal-facility/. Last accessed 17th March 2022.

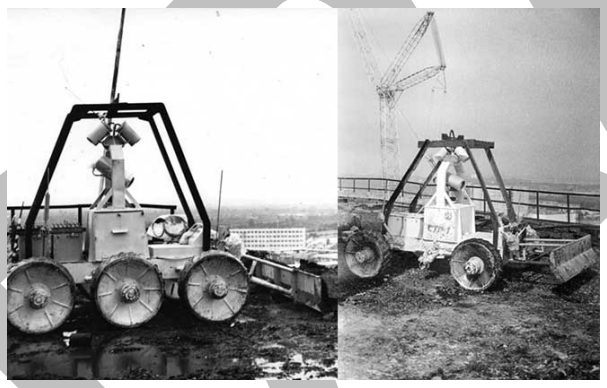

Figure 4: *Lunokhod STR1 - On roof of ChNPP 1986*

Figure 5: *Joker Robot Supplied by German 1986*

Testing of the functionality of the Arduinos will consist of the following:

a. Being able to upload Sketches/Code to the Board/PCB
b. Testing the operation of a variety of output/inputs by using:
    i. LEDs (Light Emitting Diodes)
    ii. Temperature Sensors
    iii. Servos
    iv. Buzzers/Sound Emitters
    v. Distance Sensors

vi. LCD/TFT Screens

5. **Potential Shielding materials to prolong Radiation-Induced Damage (RID)**
   I will identify a variety of materials that could potentially be used to shield against Radiation-Induced Damaged (RID) and prolong the life of the Arduinos and run several tests during and after irradiation to assess their functionality. Potential materials I would like to consider are (in no particular order):

Copper	Aluminium	Steel
Lead	Wood	Acrylic
Iron	Graphite	Water

Table 2: *List of potential materials used for Radiation Shielding*

6. **Arduino Temperature Tolerance Investigation**
   I will acquire time in a dedicated laboratory (TBC) to subject several Arduinos to a source of extreme heat and extreme cold to ascertain at what temperature they cease to function, this will provide valuable insight towards my year 3 field experiment.

   I will source a specialist laboratory services to conduct this service to ascertain how long the Arduino platform can operate at when exposed to concentrated heat source as well and cold source and whether the Arduino can function when frozen.

7. **Single Node & Hub Development and Testing of the AWSN**
   I will conduct a local experiment using a variety of sensors and the Arduino platforms to capture data on levels of radiation and store this data in a MySQL database for interrogation at a later date, this will act as the primary stepping stone to scaling up the Arduino Wireless Sensor Network to include multiple nodes, connection to a MySQL Database to collect and captured data, I will even look at using Microsoft Azure IoT Hub and the Storage Databases associated with Azure.

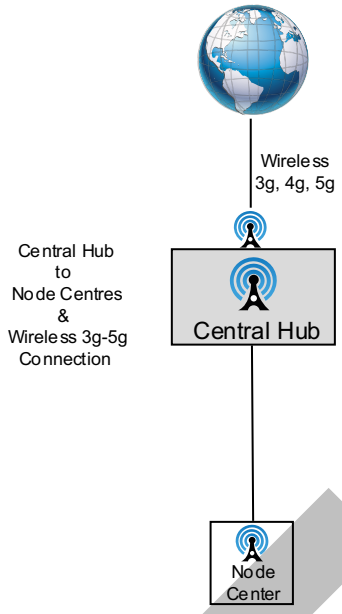

***Figure 6**: Prototype AWSN Node to Hub to Internet*

8. Arduino based Wireless Sensor Network

I will design, build and develop an Arduino based Wireless Sensor Network that will be deployed in and around the Chernobyl Exclusion Zone (CEZ) to monitor levels of radiation and meteorological factors over 12 months. The Arduino will need to withstand the harsh environment of Radiation throughout the field research element as well as withstand the weather conditions within the zone, as it will need to be able to handle the heat and extreme cold. A variety of sensors will be attached to the Arduino (Geiger Counter, Temperature, Humidity, Barometric, Moisture, Wind, Light, and many others) to collect the required data, I plan to store the data in a MySQL database for future interrogation and also an internal micro SD Card, I will possibly explore the use of Microsoft Azure IoT Hub and Azure Databases to store the data within the cloud.

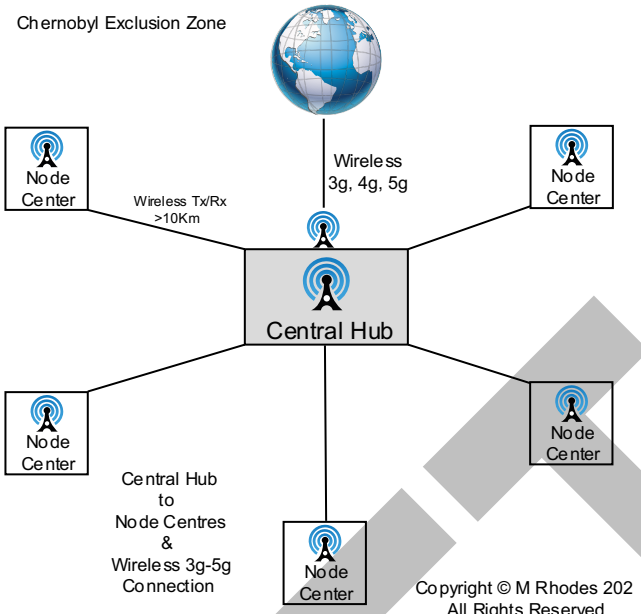

Figure 7: *AWSN Central Hub to Central Nodes Topology*

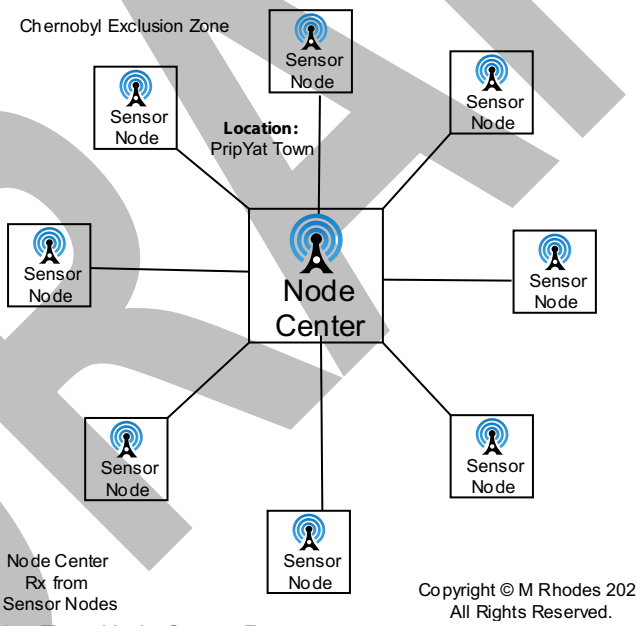

Figure 8: *AWSN Sensor Nodes Tx to Node Centre Rx*

9. **Powering the Wireless Sensor Network over 12-months**

   I will investigate possible ways of powering the Arduino Wireless Sensor Network throughout the field experiment as travel back and forth to change out batteries will be very costly and timely, I will look at Solar, Wing and Hydro Electric power solutions I will also investigate a magnetic powered solution similar to bicycle dynamo.

   I will investigate the feasibility of using Solar panels to charge a battery during the day and power the node at the same time. What systems are available on the market to charge and power the node using wind power and may be design and develop a hydroelectric solution where there is moving water.

10. **Year 3 field trip planning***

    I will plan Who, What, Where, When and How I will be deploying to the Chernobyl Exclusion Zone to deploy the Arduino Wireless Sensor Network.

    **This aspect will be dictated by the current climate of the Russia/Ukraine conflict at the time, a fallback option may well be Fukushima a secondary fallback option could be Windscale UK and surrounding areas.*

11. **Design and develop a web-based User Interface**

    I will design and develop a web-based User Interface to monitor the data coming in from the Arduino Wireless Sensor Network from the Chernobyl Exclusion Zone. I will explore using R as a data analysis tool to interrogate data.

12. **Data set analysis**

    Reviewing previously collated data sets, analyze how levels of radiation have dropped or increased in and around the zone over the last 38-40 years. By the time I get to submitting my thesis document, it will be the 40th anniversary.

Ethical Considerations:

Human Experimentation:
My research will not contain any experimentation on humans in any form.

Animal Experimentation:
My research will not contain any experimentation on animals in any form.

Data management and Data Privacy:
Any data that is captured that contains personally identifying information will be anonymised before being published.

Safety Considerations:

I plan on conducting experiments that will involve working around hazardous materials (Cobalt-60) at Henry Royce Institute (HRI), I will be expected to adhere to that institution's health and safety guidelines and handling of hazardous materials and waste in a safe and controlled manner.

Contaminated Materials:
All or any materials or equipment that becomes contaminated will be disposed of correctly and with the guidance of the Environment Agencies recommendations for the United Kingdom, any materials that are contaminated during the field experiment phase will be disposed of on-site and not brought back to the United Kingdom.

Why Me:

I would like to undertake a research degree as I have the passion and drive to undertake such a challenge, I am fascinated by the whole Chernobyl incident, the lead up to the incident as well as the aftermath, I have followed the installation of the New Safe Confinement (NSC) that has been erected over the old sarcophagus that was built very quickly back in 1986. I watched the progress of the build via the live web video link during my undergraduate studies at the University of Gloucestershire. I also watch the live feed when they slid the new cover over the damaged reactor building in 2017.

During my Master's degree at the University of the West of England, I undertook a module on the Internet of Things where we built and developed a mini sensor system to monitor an elderly person in a home, this was using the Arduino platform and the Grove Kit which contained several sensors, I developed the code to include a few extra features that were outside the scope of the project requirements but bolstered the system. I got a very high grade for completing the project side of the module. My Master's thesis/dissertation consisted of researching about Chernobyl as I wanted to design robots that could remove the Elephants foot below the damaged reactor, however, I had a slight change of direction after doing the Internet Of things module and came to the conclusions that I wanted that to be my research topic.

I feel that now is the right time in my life to undertake such an endeavour, I have a young family, I'm working (Remote Computing Lecturer/Assessor) for a local college only 1 day a week at present, so I have plenty of time on my hands to be focusing on a research topic.

I thoroughly enjoy researching topics of interest, I would like to be at the pinnacle of my research field, I am under no illusion that this will be an easy process, I am well aware that many long hours will be needed and a lot of sacrificing personal and family time to complete research. I am also well aware that there will be failures as well as success along the way.

Timing:

Start: September/October 2022 – Remote Study.
End: July-September 2026.

Year 1 (2022 – 2023):
By the end of the first year, I will have completed all background reading around the subject of Chernobyl, completed the Tx/Rx Distance investigation and published my first peer-reviewed paper on this topic,

I will have completed the GPS Accuracy investigation and again published a peer-reviewed paper, I will also have acquired time on the Gamma Irradiator completed the Radiation Tolerance Investigation and have completed the write-up and published a peer-reviewed paper.

I will be well into writing my main thesis document, have agreed on a title and working on the main literature review surrounding my specialist subject.

I will have begun to design and build a working prototype of the Arduino Wireless Sensor Network (AWSN).

Year 2 (2023- 2024):
By the end of the second year of study, I will have completed the Temperature Tolerance Investigation and written and published a peer-reviewed paper, Designed and built a fully working prototype of the Arduino Wireless Sensor Network, this will be the first iteration of the Wireless Sensor network that will be deployed in and around the Chernobyl Exclusion Zone in Year 3.

Continuation of writing the Main thesis document, adding previous research to the document from year 1.

By the end of year two, I will have completed planning on my year 3 field experiment,
I will have begun developing the Web-Based User Interface to monitor the AWSN.

Year 3 (2024 – 2025):
January (2025) I will plan to deploy the Arduino Wireless Sensor Network in and around the Chernobyl Exclusion Zone, design, develop and integrate a Web-based UI and connect to the MySQL database to interrogate the data that has been recorded from the Chernobyl Exclusion Zone.

Year 4 (2025 – 2026):
January (2026), I will plan to recover the Arduino Wireless Sensor Network from the Chernobyl Exclusion Zone.

I will have finished collecting all the equipment from the exclusion zone, decontaminated and safely disposed of what cannot be used, all equipment will be thoroughly cleaned and inspected for radiation damage and disposed of safely and correctly. I will analyse the data that has been captured from the zone,

I am anticipating having some holes in my data due to several sensors succumbing to radiation damage, however, I am hoping to have alleviated this issue with the radiation tolerance investigation conducted previously.

By the end of year 4, I will have a fully completed thesis document to present for assessment and complete a Viva.

Education Requirements:
I will undertake taught modules as directed and agreed by my Supervisor, must be subject/topic relevant to my research program, any modules to be confirmed.

With permission of the University I would like to attend the following modules:
CT5061 – IoT Development

Publications:

Year 1:

1. Transmission (Tx) and Receiving (Rx) Modules Investigation
2. GPS Module Accuracy Investigation
3. Radiation Tolerance Investigation

Year 2:

1. Arduino Temperature Tolerance Investigation
2. Powering the Arduino wireless Sensor Network over 12 Month period.

Year 3:

Year 4:

1. Data Set publication.

Funding:

I will apply for funding from Student Finance England (SFE) for the Postgraduate Doctoral Research Loan **[#]**. I will also be financially supported by current employment and savings.

Gov.UK. (2022). *Doctoral Loan.* Available: https://www.gov.uk/doctoral-loan. Last accessed 31st March 2022.

Progression after PhD:

I am planning on entering the field of academia either in a research role for postdoctoral research projects or progress to teaching at college or university.

I will possibly progress on to gain further teacher training qualifications for example PGCE Secondary ITT with Computer Science to become a qualified teacher in secondary schools. I have a genuine passion for becoming a teacher, however, I would like to gain a doctorate in computer science first.

References:

Abc123

List of Tables:

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