New Model of Emergency Communication for Disaster Relief in Remote Areas

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***Abstract*—Even in the 21st century, modern communication technology is still affected by natural disasters and political turmoil which threaten people's lives and make the Internet or mobile phone networks unavailable for use. This work is based on constructive research which resulted in a proof of concept system that uses shortwave radio technology to provide a one-way communication system. A message that a user writes on their smartphone, which is connected to a small preset transmitter, is sent out to a receiver in another part of the world where the message can then be posted on the Internet. This system is a cheaper alternative to other shortwave radio transmitters, and has potential for improvement.**

Keywords—embedded system; smartphone; shortwave radio; disaster relief; emergency communication

I. INTRODUCTION

As evidenced in recent political events and severe natural disasters, such as the Arab Spring, the 2010 Haiti earthquake and the 2011 earthquake and tsunami in Japan, modern telecommunication is still susceptible to both government interference and the unpredictable harshness of nature. For example; during the 2011 uprising in Libya the government stopped all internet traffic in and out of the country [1]. During such events the lives of many people were endangered, and with local infrastructure suddenly deteriorated, they were in desperate need of foreign aid which could no longer be reached by usual means. From this came the idea for developing an alternative mode of communication for use in emergency situations, one which would let individuals in life-threatening conditions still have a chance to connect to the rest of the world.

II. OBJECTIVES

How can people communicate over long distances in a way that is both cheap to use and not too technically advanced for the user when there is no internet and no mobile phone networks available? The most fundamental requirements for such a system would be:

- Easy to use – no advanced user expertise required.
- Easy to install, if not already in place.
- Cheap to operate.
- Long range communication; at least 1000 kilometers.
- Available for many simultaneous users.

An existing solution to this issue is the satellite telephone, but it has a high initial cost as well as a high minute rate. It is also illegal or restricted in some countries, and there are only a handful of operators to choose between, some of which do not have complete global coverage.

If a shortwave (SW) radio transmission can be originated from a person's smartphone, it would remove the barrier of technical knowledge required for SW radio transmitting, since a person is familiar with their own phone. But a smartphone cannot transmit SW radio signals on its own, and a mobile application would require an internet connection, therefore the phone would have to instead be connected to a device that can transmit these signals. This device can be preinstalled with software and hardware that, when connected to a user's phone, can take a text message and send it as a SW radio signal. All the user has to do is set up the device and its antenna, connect their phone to it, write a text message and press a "submit" button. This way the user does not have to concern themselves with what frequency to transmit at, or how much power to use, or any other advanced technical requirements. Once transmitted, the signal can be picked up by a receiver which then converts the radio signal back to text, so that it can then be posted on the Internet where it will have a bigger reach. The system's ease of use means that it can be used by anyone who is familiar with a smartphone, since they do not need to know how SW radio transmitting works.

III. AIM

The aim of this work is to develop a proof of concept for a one-way emergency communication system that uses shortwave radio signals to broadcast a user's message to a different part of the world. What are the possibilities available for building a shortwave radio based communication transmitter? This work systematically analyzes the potential technological choices that can be used for the system and provides recommendations for suitable technologies to be implemented for the different parts of the system. These

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alternatives together make up a proof of concept, which is tested for its overall functionality. This is done primarily with ready-made components based on the Arduino platform, since it is an established and open source tool with high flexibility and potential. Based on the five general requirements listed previously in Objectives, a pre-study is made, including a detailed list of 17 requirements with three different categories: minimum, ideal and nice to have.

IV. Method

The chosen working method for this research is the systems theory, which according to Pahl et al. [2] is an important and effective way of designing a technical system. The first steps of this approach are problem analysis and formulation, which were done by producing a pre-study, making a list of specific requirements and studying a number of related works. Once the research question is clearly defined, then the next steps are to synthesize and analyze a number of solution variants. These variants were evaluated so it could be decided which of them would be best suited for this work according to the work's problem formulation. After this comes system implementation, where the solution variants that have been selected are incorporated into the proof of concept.

However, sometimes these steps do not lead directly to a final result. An iterative approach must also be taken in order to produce a functional system that fulfills its requirements. Throughout development, any parts of the system that were not functioning at a satisfactory level were reiterated. The previous steps in the systems theory were revisited to analyze and evaluate what actions should be taken, before implementing these measures and seeing if they helped overcome any ongoing issue.

V. Results

The proof of concept is divided into three solutions, explained below in A, B and C, with an overall view in D.

A. *Smartphone Connection to Transmitter*

Wi-Fi is used to connect the user's smartphone with the transmitter. The user opens a web browser and types in the transmitter's IP number in the address bar to interface with it. This is done through a simple web page where the user writes a message into a textbox and presses a button labeled “submit.”

The basis for the transmitter hardware is an Arduino Leonardo microcontroller. Arduino is an open-source platform that is made for programing and constructing electronics. Like other microcontrollers, Arduino is a circuit board with a processor chip that can be programmed to do different things: it can read information from input devices e.g. antennae, sensors, trimmers, and it can also send data to output devices like LEDs, speakers, LCD screens and DC motors. With wi-fi or Ethernet shields the Arduino can also be connected to the Internet. A shield is a circuit board expansion that can be connected to the Arduino circuit board. The software uses a simplified variant of C++ to program the board, which makes it easy to learn and to program. Unlike most previous programmable circuit boards, Arduino does not need to have a separate piece of hardware to load new code onto the board; this is made easy by using a USB cable connection [3]. It also has a small size, 5 by 7 centimeters, which makes it very portable and thus ideal for use in this proof of concept.

An Ethernet shield was chosen since a wi-fi shield, while ideal for this work, would only allow the Arduino to function as a wireless client and not a server. The Ethernet shield was connected to an AP (Access Point), which would assign IP addresses for all clients that would connect to the transmitter. This way the transmitter uses wi-fi so that users can connect their phones to it.

To fulfill the ease of use requirement, the connection process is made as easy as possible. Following the simple instructions enclosed with the transmitter, the user switches on the transmitter and activates wi-fi on their phone. They see the SSID for the transmitter's wi-fi network, e.g. “Transmitter 145”, and connect to it. After successfully connecting, they open the phone's browser and go to the URL specified in the instructions. This shows them a web page where they cab write down their message. Once the message is entered and the user has pressed the “Submit” button, the next step is transmitting the message, which is explained below in B.

To validate user friendliness, a sample of test users were chosen at random to connect to the transmitter using their own smartphones to send a message. The testers were able to complete all steps with an average time of one minute and thirty-one seconds, and 90% of them found the system easy to use.

B. *Transmitter Radio Signal*

A number of various digital radio modes were studied during the planning stages, including Hellschreiber, QRSS, RTTY and a few others. Through this it was discovered that the use of Hellschreiber requires separate decoding hardware, and RTTY requires a modem that was not available. However, an Arduino compatible QRSS shield was obtainable early on in the project, which made the decision to work with QRSS for the proof of concept easier, instead of risking any potential delays.

The transmitter is composed of the aforementioned Arduino Leonardo and Ethernet shield connected to a QRSS shield, which is then connected to a dipole antenna. Here the user's message string is converted into a Morse code radio signal and sent over shortwave radio. In this proof of concept the transmitter only has to be programmed once, after which it can be used from an independent power source. The chosen QRSS Arduino shield, made by QRP Labs [4], is a predefined crystal controlled Arduino compatible circuit capable of transmitting radio signals with QRSS. The shield comes with prewritten code, which can only transmit a fixed string of a text already defined in the code, ideally the user's radio call sign. For the purpose of this work, the code was modified so that instead of a static message it would take whatever message a user enters from their phone, by filtering the HTTP header of the web page to eliminate any unnecessary characters, and save it as a string variable so that only the user's written message is converted into a radio signal.

The dipole antenna was chosen since it is effective at transmitting shortwave signals without needing any specific directivity, which means that the end user does not have to consider directivity when using the transmitter. With QRSS, the transmitter operates at a frequency ranging around 10.14 megahertz, so the wavelength is calculated in (1) to be 29.59 meters.

$$\lambda = c / f = 3*10^8 / 10140000 = 29.59 \quad (1)$$

To construct a half wavelength dipole antenna, the required length of the antenna would be the wavelength divided by 2, which is 14.8 meters.

The wire was cut into two ends at 7.4 meters each and fed with a coaxial cable to the QRSS shield. The power outputted by the transmitter and into the antenna has a peak-to-peak voltage of 6.2 volts. With a resistive load of 100 ohms, the root mean square is used to calculate the power of the signal, which equals 96 milliwatts according to (2).

$$P = \frac{\left(\frac{\sqrt{2}}{2} * Vpp\right)^2}{R} = \frac{v^2 p}{R} = \frac{3.1^2}{100} = 0.096 \quad (2)$$

While this was reasonable for the QRSS shield, the signal was not strong enough to be seen on any shortwave receivers observed online during development, so an amplifier was assembled and added, increasing the power into the antenna. Now with a peak-to-peak voltage of 19.4 volts and a resistance of 50 ohms, the power is calculated to be 940 milliwatts (3).

$$\frac{\left(\frac{\sqrt{2}}{2} * Vpp\right)^2}{R} = \frac{6.9^2}{50} = 0.94 \quad (3)$$

C. Radio Signal to Receiver

The receiver used for local testing consists of an Afedri SDR Net receiver connected to a computer with Windows XP and the following software: CuteSDR [5] for demodulating the signal, CwGet [6] to decode the signal into readable characters and N1MM Logger [7] to save the message as plain text. From there the text can be directly saved and posted on any website.

Due to physical limitations regarding the feasibility of traveling more than 1000 kilometers to actually receive the shortwave transmitted message, signal reception for the proof of concept was split into two stages. In the first stage, using the equipment as explained further below, the signal was decoded so it can be shown in plain text. The second stage involved transmitting the signal out in the world with online radio receivers as marks to see how far away the message can reach. Both stages were developed simultaneously.

The radio signal sent out by the transmitter is picked up by a computer with an SDR (Software Defined Radio) receiver, which reads signals via its antenna and uses the computer's sound card and software, CuteSDR, to process them as audio signals so they can be decoded by other software on the computer. In this proof of concept these signals are decoded by CWGet, which displays letters and numbers based on which Morse code signals they correspond to. The program N1MM Logger reads these letters from CwGet and displays them in plain text which can then be saved on the computer.

D. Overview

All three solutions are brought together to make up the whole system. It starts with the user connecting to the AP and writing a message on their phone which is sent through the Ethernet shield to the Arduino. The message is broken down where each letter or number is represented by a byte which is sent as a shortwave Morse code signal. This signal travels and reaches a receiver which then decodes the message.

During development, the transmitter's signal reached receivers located in Belgium, England and Italy. These receivers have locator codes that enable the calculation of the exact distance the signal has traveled. Amateur radio users utilize a coordinate system known as the Maidenhead Locator System, using geographical coordinates based on latitude and longitude. The proof of concept transmitter's Maidenhead locator is JO65LO in Malmo, Sweden.

The first confirmed receiver is located at coordinate JO10TT in Maarkedal, Belgium, and the distance from the transmitter to this receiver is 820 kilometers. The Morse code signals do in fact correspond to the signal that has been transmitted. Another receiver, found 1141 kilometers away from the transmitter while it operated with 1 watt of power, is located at JN55GL in Desenzano Del Garda, Italy. The signal is also confirmed to reach a radio beacon at IO91ML in Reading, England which was 1028 kilometers away from the transmitter, this time while it was transmitting with a power of 100 milliwatts.

VI. DISCUSSION

As originally intended in the list of specific requirements, all minimum requirements are successfully fulfilled and even most of the ideal requirements as well. User friendliness has been important throughout development; allowing a person who is in an emergency situation to use their own smartphone gives them a great advantage since they are familiar with their phone and do not have to learn how to use an entirely new device. The HTML page and input process are also made simple, and have been tested for compatibility with both Android and iOS smartphones. The user enters a message for sending which is transmitted multiple times and has been proven to reach least 1000 kilometers without the need for a pre-installed application. The transmitter uses a non-directional half-wave dipole wire antenna and its small size makes it easy to carry it around. With the use of CwGet and N1MM Logger it is possible to obtain the received transmission in plain text so it can then be shared online.

While all of the minimum requirements are fulfilled, as well as most of the ideal requirements, there were some exceptions such as encryption, use of solar power, and high capacity messaging. But since these requirements fall into the "ideal" and "nice to have" categories, they are not critical for the success of this work but can certainly be an asset.

The transmitter only uses a total power of 3 watts during operation, low enough to be powered by batteries or even solar power. Only a power adapter has been used during development but it is entirely possible to connect the device to a solar panel which can generate enough power to operate the transmitter. The transmitter has a power of 3 watts, and for it to be working 24 hours per day would mean that it uses 72 watt hours, or 0.072 kilowatt hours of energy. To determine a suitable solar panel, two things must be considered: the first is how many sun hours are available, which is the duration of sunshine in a single day, and the second is the efficiency of the solar power system, since not all solar energy can be used or stored. To obtain an approximation, a calculation is made where the number of solar hours is five, and the system efficiency is 70%. One day of charging with a solar panel can be calculated to produce 0.072/5= 0.014 kilowatts, which when adjusted for efficiency is 0.014*0.7= 98 watts. This means that a 100 watt solar panel is suitable for powering the transmitter, and it can be connected to a 12 volt direct current battery which charges during the day and allows the transmitter to work at night when there is no sun. Powering a 3 watt device with a 12 volt battery means it has a current of 0.25 ampere. A 12 volt battery with a capacity of 50 ampere hours, such as a typical car battery, can power the transmitter for 200 hours before being completely discharged. However, for the battery to remain effective it should only discharge 50%, meaning that it can work continuously for 100 hours before having to be recharged.

While the transmitter has successfully propagated its signal more than 1000 kilometers to different locations, an issue faced during development was the limited number of online receivers. Most of them are located in Western Europe, and many of these were at a location less than 1000 kilometers from the transmitter, such as the ones in Sweden, Norway and the Netherlands.

The Arduino has a very small working memory, called static random access memory (SRAM), which is only 2 kilobytes. It cannot perform all the required tasks of receiving a message from a user's phone, converting it to a radio signal and sending it to the QRSS card simultaneously or for more than one user at a time. This means that while many users can connect to the transmitter via wi-fi, only one of them can send a message at a time. This is because text is saved as string objects in the Arduino's SRAM, where each character is stored as one byte. Since the SRAM saves the unfiltered text as a string object, and then filters it and saves it as a new string object, this means that the SRAM becomes full very quickly. An unfiltered message has a maximum size of 160 bytes, before it is filtered and stored as a new string variable with a maximum of 140 characters, meaning that each message requires 300 bytes of SRAM to process. While there is enough memory for multiple messages, the Arduino can only run one process at a time, so it is not possible for it to process two different messages from two different users simultaneously. Though once a message is written, filtered and converted to a radio signal, the final step of the process is looped and the message can be broadcast multiple times for many hours on end.

During the pre-study there were many technological choices considered for building a communication system based on shortwave radio. And despite the limits due to budgetary concerns as well as its general requirements, the proof of concept produced by this work shows that it is possible to develop a shortwave radio communication system that fulfills four out of five general requirements. The only requirement that has not been fulfilled is the ability for many simultaneous users due to the limitation of the QRSS transfer speed. This can be resolved if a faster mode, e.g. PACTOR II, is used in combination with a more powerful processor. Then it would be possible for 10000 messages to be sent in the span of 12 hours, which is feasible with 25 transmitters for an estimated time of 2 minutes per message, or 4 minutes per message with 50 transmitters. In the case of PACTOR II, which has a speed of 87.5 B/s, this is enough time for the message to be sent multiple times.

Another issue faced during development was ensuring that all local laws regarding radio transmission were followed correctly. In Sweden, the Swedish Post and Telecom Authority, also known as PTS, is the government agency that regulates electronic communication such as the Internet, telephony and radio. According to the PTS Code of Statutes [8]:

- An automated transmitter should always be identifiable by sending a call sign in Morse code, or as a voice message, or by any other means.
- The call sign should specify the person responsible for the automated broadcast, who should have an amateur radio license and an authorized call sign.
- Whoever starts or uses an automated radio transmitter should have an amateur radio license and an authorized call sign.

The supervisor for this work is a licensed radio operator, and when working with the transmitter, including the antenna, it was always placed in his office and started by him. The rest of the time spent working with the transmitter during local testing was done in the same building where he was nearby in his office, and with a dummy load attached instead of the antenna. This way the transmitter can only broadcast its signal at a very short range, which exempts it of any license requirements and allows the system to be developed and tested without breaking the law.

For the system's intended use, international law must be taken into consideration. In this case it is the International Telecommunication Union (ITU), a United Nations agency, which regulates telecommunication worldwide. And according to Article 25, section §1 of the World Radio Communication Conference 2003 [9]:

- Amateur stations may be used for transmitting international communications on behalf of third parties only in case of emergencies or disaster relief. An administration may determine the applicability of this provision to amateur stations under its jurisdiction.

From this it is interpreted that the transmitter is acting as an amateur station, since it fulfills the same purpose but is transmitting automatically and continuously for a certain period of time. The third parties are interpreted as the people using the device to send out their emergency messages. “Emergency or disaster relief” can be applicable for natural disasters as well as political instability. The clear distinction of "emergency or disaster" means that there are situations other than natural disasters where amateur radio may be used to communicate internationally. An emergency situation can occur in a country without being caused by a natural disaster, e.g. the Arab Spring revolts.

VII. CONCLUSION

After studying various modes of digital radio, this work has successfully produced a proof of concept for a one-way emergency communication transmitter that can send a user’s message to a different part of the world where it can then be posted on the Internet. The transmitter fulfills most of the basic requirements established at the beginning of the study, with the exception of sending multiple messages from multiple users simultaneously. Regardless of this, the transmitter succeeds in other aspects; it uses very little power, transmits a signal that can reach more than 1000 kilometers, and is easy to both install and use. There is good reason to believe the signal transmitted can reach more than the observed distance, but this remains unconfirmed.

With the Arduino's limited memory, it is not currently possible for many users to write and send their messages at the same time, or to have them saved and queued. This can be resolved by using a different microcontroller, one with more memory and a more powerful processor, as a basis for the system. The QRSS mode which is implemented in the proof of concept has proven to be capable of fulfilling most of the requirements of this work, with the exception of the high capacity multiple user requirement. Despite being slow, its signal works with very little power needed to operate it. Even with limited resources this work has still produced satisfying results, which may be developed even further. The use of an iterative process during development has helped overcome many of the problems and limitations faced during various stages of work, and the system is validated to ensure it operates as intended.

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