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Portable Cell Initiative

Project Proposal

Submitted for the

Wireless Innovation for a Networked Society Challenge by Mozilla and the National Science Foundation

Off-the-Grid Internet Challenge

USC Min Family Social Entrepreneurship Challenge 2017

OVERVIEW

After several hurricanes earlier this year, Puerto Rico, Houston, and other areas in the United States remain devastated. During and after such tragedies entire communities are left without critical resources, including any way to contact the outside world. Cellular service, a system taken for granted in everyday life, becomes a crucial tool for calling for emergencies, coordinating responses, directing aid, and contacting loved ones. Even regularly working cellular networks can collapse, such as when mobile systems overloaded and became temporarily paralyzed after the Boston marathon bombing. After natural catastrophes so severe that power lines and cell towers are destroyed, locals may be unable to request assistance, contact family members and friends, and coordinate rebuilding efforts while emergency workers become effectively stranded and unable to communicate for long periods of time.

After Hurricane Maria struck Puerto Rico, the Economist reported that “the lack of electricity and communication set off a chain reaction that hindered the entire disaster-response effort, complicating everything from delivering food to burying bodies.” Weeks after the disaster, only 5% of the power grid and 20% of phone towers have been repaired. Cars pile up on the shoulders of roads near phone towers to use their phones before entering more rural areas. A decentralized solution is required to connect communities to the outside world even without power or Internet connectivity.

The solution named the “Portable Cell Initiative” tackles the challenge by developing a small, portable, and light system that acts as a temporary cell tower. Using many, smaller units called “microcells” can allow a quick emergency response that creates a resilient network by linking up to adjacent microcells. The PCI cellular tower can be set up quickly by anyone, even those with little technical experience. The cell tower connects to mobile devices through 2G protocols without the need for new SIM cards. The tower allows users to send SMS and call other users in the network, access the internet freely, and instantly receive critical information including maps and emergency updates. The tower will connect to external networks and the internet through a satellite connection which will enable the solution to be deployed anywhere around the globe without any other infrastructure available. The cell towers may be interconnected to create an entire cellular network that is entirely independent of existing power and mobile networks.

The proposal includes diagrams, flowcharts, cost estimates, software and hardware details, milestones, and information about the team that will build the solution.

GOALS

1. Design and build a cellular radio antenna that can send and receive signals over GSM frequencies within a radius of one mile from the cellular tower.
    a. The tower's construction should be:
        i. Modular in design,
        ii. Easy to set up without prior technical experience or system knowledge,
        iii. Versatile enough to deploy in any non-polar environment.
2. Design and model the use of commercial off-the-shelf and open source hardware components to:
    a. Generate radio signals using a software-defined radio (SDR),
    b. Process information, including cell signals and requests through a server,
    c. Amplify signals from the SDR to the radio antenna, and
    d. Provide power in a portable and mobile manner.
3. Create software for the processing equipment to:
    a. Allow SMS and Calling between users connected to the tower,
    b. Allow any user to connect via 2G GSM protocols without the need of a separate SIM card other than one for a standard GSM carrier,
        i. And authenticate, monitor, and potentially throttle mobile access to maintain network stability,
    c. Allow free access to the internet without limits on which websites users may visit,
    d. Provide a landing page (which is known as a "captive portal") upon connecting via the cellular network or via WiFi that shows emergency updates, critical information, and maps quickly to disaster victims, and
    e. Allow cellular towers to connect to other towers of the same model to expand the network to a greater area.

USE

Users

Emergency responders may utilize the network to communicate rescue efforts and coordinate aid provision to disaster victims. Governments and other organizations may provide emergency information and instantaneous updates to disaster areas through the landing page and internet access. Disaster victims may also utilize the networks to check in with families and friends and access social media networks or any other necessary applications through the Internet. 3340 subscribers may be supported at most, assuming each subscriber makes six 90-second calls each day.

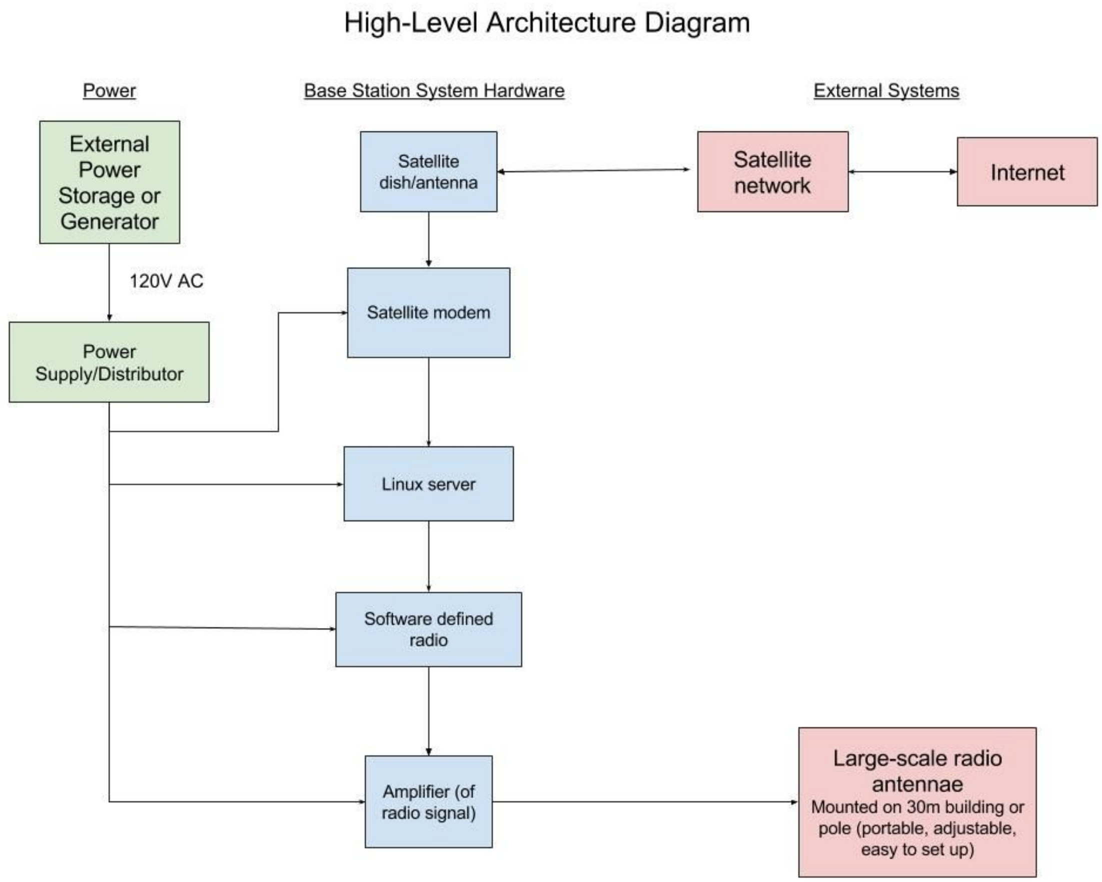
Location

The proposed solution is capable of operating globally as the global satellite network provides internet access anywhere in the world. The rugged construction of the base station will allow use in both hot and cold environments and must withstand local weather such as rain or snow. The cellular radio antenna may be stuck in the ground outside and tethered to withstand wind and extreme weather conditions. Alternatively, the tower can be placed on top of high buildings to provide additional range.

OPEN SOURCED

Inside this document, there are sometimes different options for how to construct these microcells, because as long as the software and algorithms controlling the microcells are the same, the cell towers can be built using a variety of materials, with different types of antennae, different server hardware, and different tower heights. The beauty of open sourced hardware and software is that any member of the international community can adapt the project to their environment, experiment freely, and share improvements with other members and the creators of the project. This project uses the Mozilla Public License 2.0 which provides the public with conditional permission to freely use this project commercially and distribute and modify this project.

HARDWARE ARCHITECTURE



The goal of the cell tower is to send and receive radio signals as a “cell tower” and provide calls, SMS, and internet services for mobile devices in its range. The first component in the hardware is the radio antenna, which transmits and receives radio signals through the “GSM protocol” between the cell tower and mobile devices. The antenna connects to the radio amplifier, which increases the range of the cell tower by boosting the amplitude of the radio signal. This amplifier also picks up faint signals from mobile phones far away.

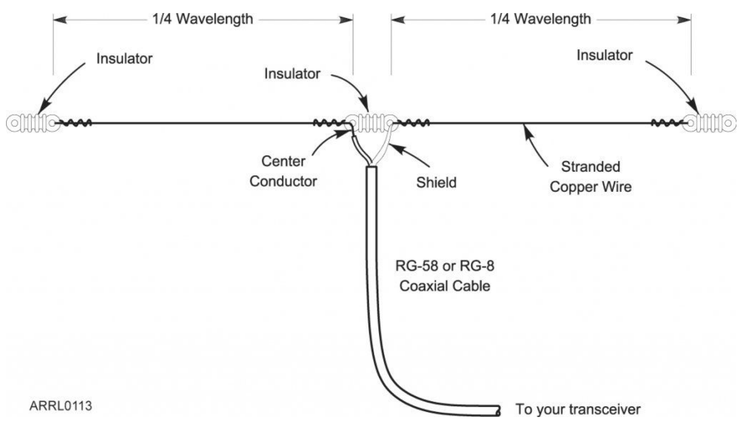
> **Note:** GSM stands for “Global System for Mobile Communications” and represents a widely used standard in mobile cellular networks that is known as 2G. 3G, or third generations systems often use a standard called UMTS, which was based on the original GSM standard.

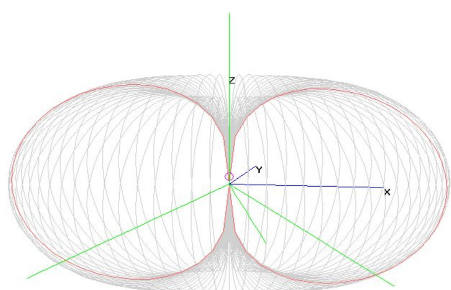
The amplifier then connects to the base station, which is the “brains” of the cell tower by processing the radio signals that are sent and received. This is made up of two components: the software-defined radio and the Linux server, which is a small, programmable computer that directs the activity on the cellular network and processes calls, messages, and web requests.

Finally, the Linux server connects to the satellite modem, which interfaces with a satellite dish or antenna to communicate with a satellite to provide internet access to the base station. Altogether, the very low-power system may be powered by a portable battery for a limited time and may connect to small solar panels or a portable diesel generator.

Radio Antenna

An antenna is simply a conductor, like a rod or wire, that converts the electrical energy sent from the radio transmitter into radio waves. Alternatively, a conductor can act as a receiving antenna by intercepting electromagnetic radiation and creating electrical currents that are sent to a radio receiver. The simplest antenna, pictured here[1] is a "dipole antenna," which consists of a quarter wavelength segment connected to the center conductor of a coaxial cable and another identical segment that is connected to the shield, which is grounded. The wavelength refers to the wavelength of the radio wave emitted or received, which varies based on the frequency transmitted or received. A dipole antenna is useful for creating an omnidirectional radiation pattern around the antenna since radio waves are generated and received from all directions perpendicular to the conductor. For example, in this image, a dipole antenna creates a donut-shaped radiation pattern. A typical issue with dipole antennae is that the impedance of the antenna is typically around 72Ω, yet this must be reduced to approximately 50Ω to match the impedance used in the feed lines (coaxial cables) and the base station. Matching impedance can significantly increase the power transfer and reduce the phenomenon of signal reflection. The grounding monopoles (which connects to the shield) can be tilted 30° from the parallel orientation with the resonant antenna to lower the effective impedance. This type of antenna incorporates four quarter-wave monopole antenna in a configuration to provide the correct impedance. In this example to the right[2], a VHF antenna is impedance matched to 50Ω while having an omnidirectional radiation pattern thanks to the three, downward-facing grounding antennae. Such





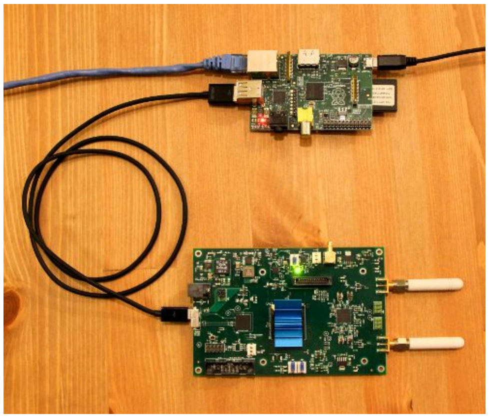
an antenna is recommended for this project as the design has low antenna gain, excellent impedance matching, and is simple to construct.

The cell tower will consist of two quarter-wavelength monopole antennae: one to transmit and one to receive. The antennae will be surrounded by plastic shrouds to prevent moisture or weather damage. Any conducting materials, like guy wires, extra cables, and metal supports, should not be used to avoid electromagnetic interference. Additionally, the antennae should be separated by several wavelengths to reduce interference further. Here are some characteristics of the system, provided 30m elevation and based on normal communication across the 900 MHz GSM band:

Characteristic	Value
Uplink Antenna Length (Per monopole)	7.9 cm
Downlink Antenna Length (Per monopole)	7.55 cm
S.W.R (50 Ω feed line)	1.18
Range	4 km

The antenna feed line is a coaxial cable, most likely of type RG-58, with small enough diameter to fit into the antenna mast. The monopoles are made of conductive wire and connect to the coaxial cable at the center of the antenna structure. The coaxial cable's ground sheath is split into three directions that plug into each of the three ground planes. The coaxial cable's inner core wire (which brings the radio signal) is directed straight upwards and acts as the actively radiating monopole.

Base Station



An simple base station example: A bladeRF connected to a Raspberry Pi. Source: Nuand.com

Software-defined Radio

A software-defined radio is a device that transmits and receives wireless signals in the radio frequency spectrum and has all physical functions of said radio as software defined[3]. A recent innovation, the software-defined radio allows programmability and incredible flexibility, as radio communications can be controlled purely through programs and without the need for any specific hardware. Recently, these innovations, many of which are open-sourced, have allowed for anyone, including hobbyists and professionals, to experiment cheaply with radio communications.

One such open-source SDR is the bladeRF series of products built by Nuand. The bladeRF x40 is, for example, a transceiver that can tune from 300Mhz to 3.8Ghz and is perfect for use in "GSM and LTE picocells"[4]. The bladeRF x40 ($420) can interface via USB3.0 with servers, like in the image above. The system is also full-duplex, meaning that it can send and receive signals simultaneously.

Nuand's own amplifier[5] can be connected to the sending and receiving connectors of the radio to amplify the radio signal. This particular amplifier contains both a low noise amplifier and a power amplifier. The presence of a low noise amplifier can improve the quality of weak signals received, which is critical for a cell tower that may receive many radio signals simultaneously with a high amount of noise. Furthermore, the power amplifier is capable of increasing the signal gain up to 33 dB in the 2.4 GHz band. Monitoring of the power output of the amplifier is available through the Linux server. Additionally, it is recommended that a dedicated power supply is connected to the amplifier to allow more power draw and thus greater amplification. The Nuand Power Supply[6] ($15) can provide up to 15W and adapts power from common worldwide, AC sources.

Linux Server

The Raspberry Pi is an excellent option for controlling a small cell site base station, because the single-board computer is cheap, mass-produced, and open-sourced. The newest iteration of the Raspberry Pi is the called the Pi 3 Model B and is available for $35 internationally. The lightweight and compact design only draws 1 to 4W of power[7] while still running a 1.2Ghz Broadcom chip with 1GB of RAM and WiFi and bluetooth support out of the box. Altogether, the Raspberry Pi can reliably run interface between the base station and satellite modem for long periods of time while producing little heat.

Another option is the Odroid XU-4 ($59), a more powerful alternative to the Raspberry Pi line of devices that includes greater processing power (with benchmark scores five to six times better than the

Raspberry Pi 3[8]) and therefore a capacity to handle much larger amounts of traffic as processing speeds scale cell tower capacity. Furthermore, even though the XU-4 has a similar form factor and size as the Raspberry Pi, it also includes USB 3.0 which is proven to be at least 10x faster than the USB 2.0 on the Pi. The Gigabit Ethernet port also reduces potential bottlenecks to the satellite modem. However, the basic XU-4 is more expensive and also does not support Wi-Fi and Bluetooth connections natively (they require adapters into the USB ports). Unfortunately, the project is not open source, although schematics are available to the public[9] and extensive documentation and tutorials are available online, similar to the Raspberry Pi. This computer weighs 38 grams.

Power

The power demanded by individual recommended components are as follows:

Component	Power draw idle	Power draw active	Power draw maximum
Raspberry Pi 3[10]	1.4W	2.4W	5.1W
Odroid XU-4[11]	4.2W	13W	20W
bladeRF x40 and Amplifier[12]	2.3W	9.0W	15W
Explorer 510 (Satellite modem)[13]	0.8W	14W	38W
Total*	8.7W	38.4W	73W

*The total power draw is based on the recommended combination: Odroid XU-4, bladeRF, and Explorer 510

The power must be introduced from a portable generator, solar panel, or battery pack to the power bus on board the PCI system. The power bus accepts one 120V AC connection and distributes that power to the rest of the components, including servers, radios, modems, and antennae. These individual components each have individual converters to draw the correct voltage from the power bus.

It is recommended that the main power bus is connected to an intermediary battery pack that accepts DC power, has a fuse to prevent damage to the circuitry, and creates smooth AC power at the correct frequency. The DC power can then come from either a diesel generator that runs temporarily to charge up the battery or a solar panel that provides an average power delivery above the required power draw over a 24 hour period.

A large variety of components off-the-shelf and custom-made will perform well in this system. For the cost estimate, a Goal Zero battery pack was chosen with 1045 Watt-hours of capacity that is capable of producing 120V 60Hz AC power and also interface with Goal Zero solar panels, such as a briefcase model that is capable of generating up to 100W of solar energy and storing it in the battery pack. A 1045 Watt-hour battery can power the microcell for around 34 hours alone when active. For serving more users or in a more intensive environment with more power consumption, it may be necessary to increase the capacity of the battery pack and solar generation of the solar panels or intermittently run a generator.

Satellite Connection

External access to the internet, calling, and SMS to external mobile devices will be connected through existing networks of satellites. Several methods exist to connect to satellite "constellations," which are large satellite networks that transmit data around the globe. Interfacing with these constellations can be done through proprietary hardware that is available from the satellite service providers. These constellations, or other satellite connections, can provide one uniform pipeline to access Internet services. Through this Internet connection, the PCI operator can connect to the web APIs like Google Voice and Twilio as described in the software architecture section.

One such satellite provider is Inmarsat which provides consumer and business services called IsatHub and BGAN to connect to a global network that covers the entire globe except for extreme polar locations[14]. BGAN, which stands for Broadband Global Area Network, does not require complex technical knowledge to set up, as the receiver and transmitter are provided in a pre-configured unit that must not be precisely aimed towards the satellite, just in the general direction. The recommended satellite modem and antenna system will be the Explorer 510 (recommended for BGAN satellite connection):

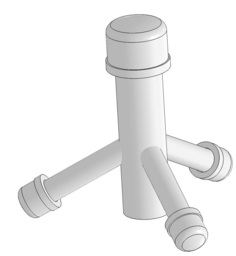
The Explorer 510[15] can provide a data connection up to 464 kBps, which is limited for multi-user operation and may present a limitation of using a BGAN setup. However, the Explorer 510 is resistant to temperature and humidity while being drop-resistant. Its IP66 rating means it is entirely water and dust sealed[16]. BGAN modems provide simple methods for achieving this initial calibration, for example, using auditory cues to aim the unit in the correct direction (which does not present any issues with language barriers) or even utilizing a smartphone app[17]. A BGAN modem such as the Explorer 512 outputs through an ethernet cable that can be connected directly to the Linux server without much setup required.

Downsides of the BGAN setup are the low bandwidth and high cost of Internet usage plans: a simple package for example that provides 30 GB at full speed then throttled data at 128 kBps costs $3595.00 per months for three months of service[18]. Other provider packages can charge up to $4,500 for the same connection of 30 GB unthrottled[19]. The most significant advantages of the system, however, are its flexibility and usefulness in diverse weather conditions. BGAN communicates through a lower frequency, the L-band which is less susceptible to rain fade than other satellite dish systems[20]. Specific models are available for BGAN communications that have the modem and transceiver sealed to prevent dust and water damage as well as protected against both hot and cold weather conditions. The costs for terminals vary from $795 to over $5000. Several terminals may be compared here.

An alternative to the BGAN system is the iDirect global satellite constellations use of VSAT transceivers (VSAT stands for "Very-small aperture terminal"). VSAT technologies utilize the more commonly recognizable satellite dishes and are more prone to interruption of service due to weather conditions in the sky, yet the system may be isolated to prevent damage due to water, temperature, dust, or other conditions. The main advantage is that the bandwidth of VSAT technologies is much higher, allowing internet access up to 20 Mbps download and 5 Mbps upload. However, many plans are still capped for usage at similarly high prices as the BGAN solutions. The base price of terminals is also similar, but slightly higher than BGAN terminals as the prices of base models start at $1,364[21]. However, mobile solutions that are designed for rough conditions and transport can be many times more expensive than even high-end BGAN terminals. The large dish and accompanying equipment also are harder to transport to a disaster location regardless of the price because of the weight and bulk. Installation difficulty also scales with the terminal's size. For these reasons, the BGAN system is the recommended satellite receiver, transmitter, and modem.

Mounting

The antenna, with four monopoles connected, rests inside of an antenna structure that is made out of PVC tubing. The wiring of the monopoles is surrounded by insulation, which fills the space between the tubing and wiring. Each PVC monopole segment is capped, and those caps sealed to the tubing to prevent water or moisture damage.



The entire antenna mast consists of two antenna structures which are helds several wavelengths apart to avoid interference. The antenna mast is approximately 1 meter long and 0.5 meters tall. The coaxial feed lines run in from the bottom of the mast to the individual antennae. The mast is also made out of PVC, which may be taken apart for transport (especially larger segments).

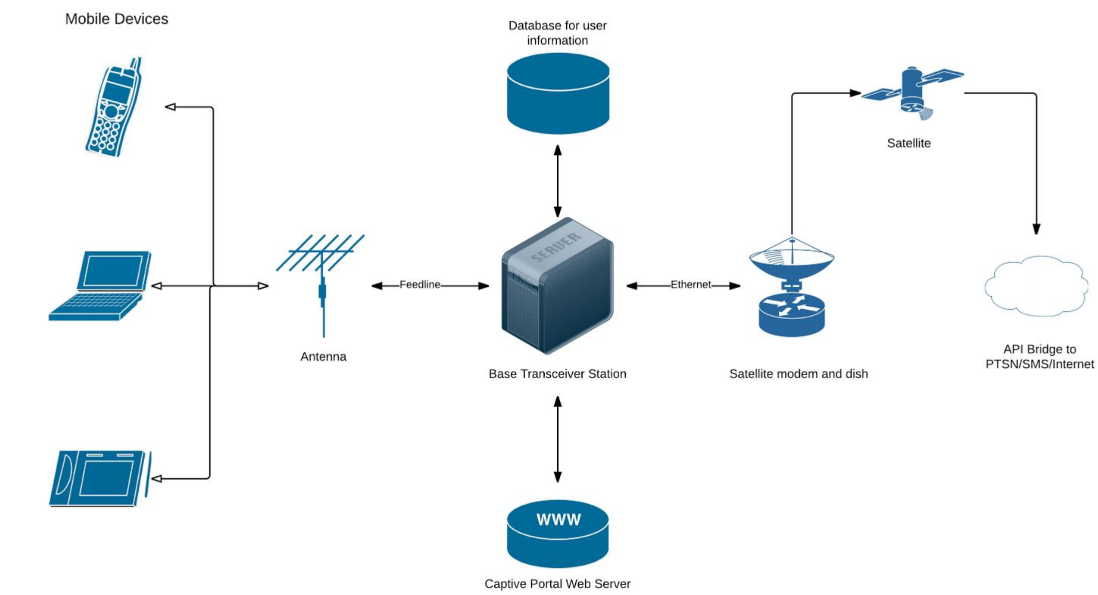
To mount the antenna mast on an existing structure, one should use a base, such as several sandbags or a plate connected to the mast to provide structural stability. Alternatively, one could lengthen the PVC at the bottom to create a larger tower. Still, it is recommended that the tower is segmented, connected by PVC joints, and strengthened with metal inserts. If using a tower, guy wires are highly recommended to provide static stability to the free-standing structure, especially during inclement weather conditions.

When constructing a large tower or handling electronics outdoors, follow location electrical codes and regulations. Safety recommendations about lightning protection, electrical safety, radiation safety, and other guidelines are available here (we disclaim any liability).

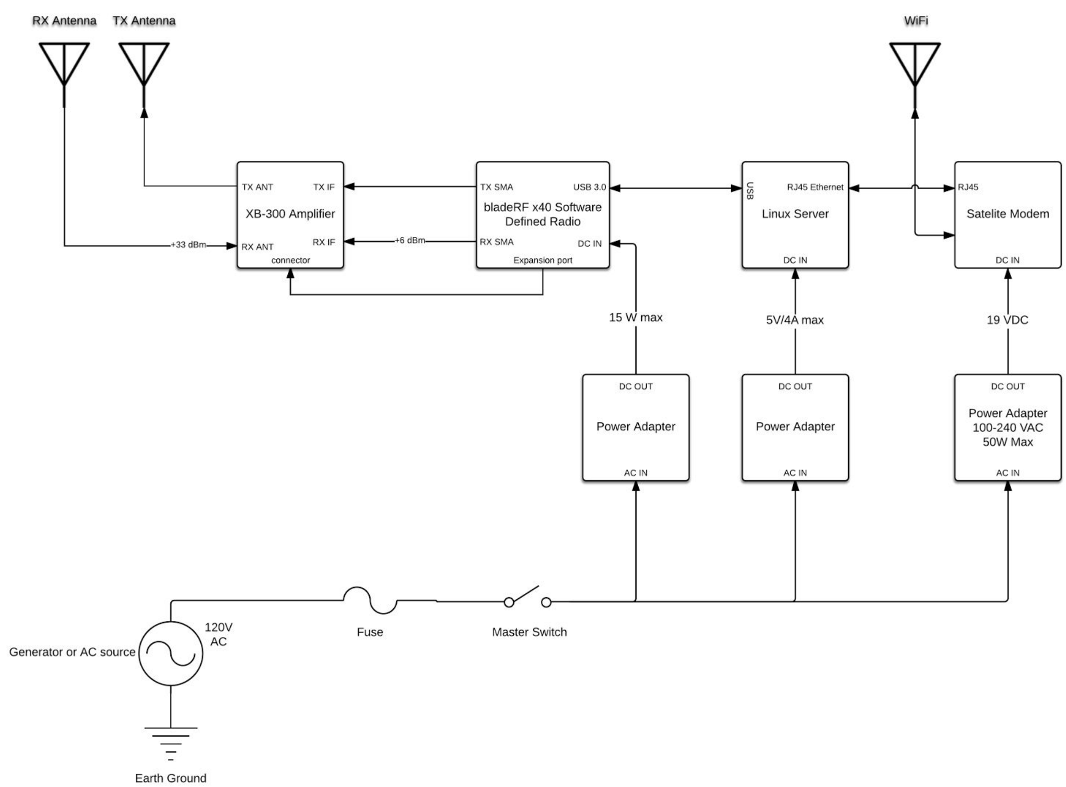
Weight Estimate

Component	Weight (kg)
Base Station (bladeRF, Odroid XU-4, cabling, and housing)	3.5
Antenna Mast	1.5
Satellite Transceiver	1.4
Portable Lithium Ion Battery Pack	18.1
Solar Panel	11.7
Total weight without power generation or batteries	6.4
Total microcell weight	36.2

Additional Diagrams



Portable Cell Initiative Network Diagram



Base Station Wiring Diagram

SOFTWARE ARCHITECTURE

The software that will be leveraged is all open-source and custom scripts and commands that will be required to operate these systems are available on GitHub for free use under the appropriate license.

The software that will be running on the linux server includes OpenBTS, an open-source project for operating cellular network infrastructure such as cell towers on software-defined radios. The operating system used will be Debian, but Ubuntu and centOS are also supported and tested for compatibility. This proposal contains outlines and requirements of the software architecture and thus will serve as an overview. More details on installation and operation are available in other documents.

OpenBTS will be used to operate the “base station” and will run on the linux server to send commands and monitor the software-defined radio. OpenBTS will govern GSM (or “2G”) communications, including voice, SMS, and data services. Included in this software is further access to GPRS, an improved standard.

> **Note:** GPRS stands for “General Packet Radio Service” and allows packets to be routed under the IP protocol. It is often referred to as 2.5G (in between second and third generations).

GPRS is limited in network speed to about 40 kbps, or as fast as a dial-up modem[22]. OpenBTS-UMTS is an open-source project that allows access to faster, 3G data speeds but is still developmental and does not support voice or SMS. Therefore, the software architecture will run on a GPRS/GSM system to increase the number of concurrent users on the network and support voice and SMS, but future updates to UMTS are simple.

Other software packages utilized to provide services include Asterisk, to route calls between mobile devices, SIPAuthServe, to register and allow calls to specific handsets, and SMQueue to handle SMS storage and later delivery if the handset is unavailable. OpenBTS converts GSM traffic to use the SIP (Session Initiation Protocol) and RTP (Real-time Transport Protocol) and thus allows voice and SMS connections within the network. Another technology called “OpenRegistration” allows users to create their own subscriber identities as custom SIM cards or registered phone numbers are not required on these temporary networks. Handsets can talk to the cell tower over SMS to create accounts and self-assign phone numbers.

Access to the outside world is available solely through the satellite modem connection that provides a gateway to the Internet for the linux server. Requests through GPRS through the TCP/IP protocol may be fulfilled easily, yet calls and messages through SMS that are directed out of the network are more difficult, as they must be bridged to the PSTN from the SIP and RTP protocols within the cell network.

Note: Connecting to the outside world requires an ITSP or Internet Telephony Service Provider, which routes SIP/RTP signals to the PSTN, or Public Switched Telephone Network which "is the network that carries your voice calls when you call from a landline or cell phone" and "refers to the worldwide network of voice-carrying telephone infrastructure"[23].

Services that can GSM devices to the PSTN include Google Voice and Twilio. For example, an exploration on connecting voice services from Asterisk to Google Voice may be found here[24].

Captive Portal

A central feature of the Portable Cell Initiative is to, provide not only means of communication between members of the community and emergency workers but also facilitate the response to the disaster at hand. A captive portal is a default web page that appears upon connecting to a network with a web browser and is a common feature of large WiFi networks at airports or hotels. Network traffic may be redirected to a special webpage, which provides users:

- Official updates or warnings from the government or other emergency services
- Maps of the surrounding area with updates, for example through a service like Google Crisis Maps
- Useful web resources and telephone numbers to call
- A forum for community peer-to-peer assistance, for example connecting people who request asylum to other locals who offer places to stay

Note: Connecting through a captive portal is often a means of limiting access to the internet through a network. No such limitation exists, and users can exit the portal and browse the web freely (thus visit any webpage or use any web service). Users can access the web portal like a website at any time.

COST ESTIMATE

On a per microcell basis using recommended components:

Component	Cost
Odroid XU-4	$59
BladeRF x40	$420
XB-300 Radio Amplifier	$149
Explorer 510	$2176
Housing, cabling, wiring, antenna, structures	$50
Battery Pack (Goal Zero Yeti 1000 Lithium Portable Power Station)	$1299.95
Solar Panel (Boulder 100 Solar Panel Briefcase)	$299.95
Satellite Internet service package*	$4695/month
Total (cell tower without power infrastructure)	$2854
Total	$4459.90 + $4695/month

*Assuming unlimited data usage worldwide. Actual rates depends on data used and geographic location

The satellite Internet package pricing for BGAN depends on the location of the usage and the extent of data usage by the terminal. Typical plans for unlimited data usage (with 30 GB unthrottled) cost $4,695/month for a 3 month period while the BGAN Link Geo plan which is geographically limited to certain areas is cheaper at $1,750 per month for 3 months. Typical plans that are not unlimited price the data connection at $4-5 per each additional MB but have low upfront costs[25].

Compared to other solutions, such as sending balloons into the stratosphere, or operating full-scale cell tower infrastructure which costs millions of dollars, this solution is several orders of magnitude cheaper.

MILESTONES

Design Phase

Complete initial research, cost estimates, CAD models, network and hardware diagrams, and system architecture design. Begin software design by writing automated scripts for the base station server.

Prototype Phase

Purchase and test base station components with a small antenna and low-power setup. Finalize software and protocols to allow full operation of a minimum of two smartphones on the network, including SMS and calling between the mobile devices, access to the captive portal for information, and external internet access.

Full-Scale Testing

Create a prototype of the large scale radio antenna and acquire permission to test in a designated area with an FCC experimental radio license to calculate the actual range and network capacity of the system. Test additional functionality like access to the tower with SIM cards from other cellular network providers. Place the base station equipment in prototype casings and test the power supply supplying the system disconnected from the electrical grid. Complete weather testing of all components, including temperature extremes, rain, and snow.

Deployment

Complete equipment required for deployment of the system into real-world scenarios, including packaging of the full-scale equipment and writing manuals in several languages for ready-use in several countries. Finally, confirm that the system allows connection between multiple cellular towers to create a mesh network, even when the towers are spaced far apart.

COMPETITORS

AT&T ARMZ

A similar solution exists by AT&T for government and enterprise operators to create a “picocells,” or small cell sites that connect via satellite to allow communications in the wake of disasters. However, the proprietary nature of the system either requires the use of AT&T’s own satellite systems and networks to operate or requires custom solutions to be designed with experts to set up the cells. The system can only service 7 concurrent calls simultaneously per picocell[26] and is also limited to using 2G and 2.5G services. The mobile service configuration is also limited to a ½ mile radius, and the system is heavy (weighing an estimated 290 pounds at minimum). This particular system has a limited operational temperature of 5°C to 40°C[2] and the VSAT technology that is used to connect the picocell to satellites is bulky and harder to point and set up than alternatives like BGAN[27]. Data speeds of BGAN solutions may be limited in comparison, but each type of connection is well above the minimum requirements for cell tower operation[28]. VSAT solutions are also more prone to weather such as rain and extreme conditions like snow and strong winds[29]. Most importantly, the current ARMZ solution is only viable in the continental U.S. while this proposal suggests a system that would work in any environment, anywhere in the globe without any need for modification. The open sourced nature, the cheap costs of components, the flexibility of operation, and the resistivity to adverse weather conditions of the Portable Cell Initiative make it more advantageous to use than alternative ground-based solutions.

Google Loon

Google has created a solution which uses " balloons to help provide internet service to people in hard-to-reach places"[30] and has an experimental license from the F.C.C to roll out Internet service in Puerto Rico after Hurricane Maria, according to the L.A. Times. Issues for achieving connectivity in disaster areas include requiring integration with the existing telecommunication companies in Puerto Rico, as the balloons themselves cannot deliver the signals alone. The balloons suffer disadvantages, such as requiring dedicated ground links to achieve Internet connectivity and constant maintenance and care to operate. The complexity of incorporating a flying device into the system makes the solution less practical for fast deployment and reliable operation. Altogether, it is simpler to have a ground-based microcell like proposed by the Portable Cell Initiative which can exist without outside requirements for power and connection and also provide telephone communications and SMS without needing integration with existing cellular carriers. Although integration is possible to "expand" the existing telecommunication framework with microcells, service is also available as a standalone carrier without having to re-issue SIM cards to subscribers.

TEAM

Arpad Kovesdy is a freshman studying aerospace engineering at the University of Southern California in Los Angeles. Arpad is a recipient of the prestigious Presidential scholarship and member of the W.V.T Rusch Undergraduate Engineering Honors Program at the Viterbi School of Engineering. He founded the project in 2017 to address the growing need for portable systems of cellular communications around the world, and especially for disaster areas such as hurricane-devastated locations in the United States. He currently leads the software and hardware design of the project and has extensive experience with engineering front-end and back-end systems for websites and apps. He has four years of experience in robotics competitions like the First Tech Challenge and has completed research at the University of Tennessee Knoxville in Materials Science. Arpad also spends time working at the Rocket Propulsion Laboratory at U.S.C., where undergraduate students design, build and launch rockets. Arpad is the team leader of the Portable Cell Initiative.

Joseph Stafford is a freshman studying computer science at Michigan State University. He is part of the Honors College at MSU and is currently researching solutions to reducing parking congestion through building an app that reports the number of parking spots available on campus. Joseph was also involved with robotics during high school and focused on the development of autonomous guidance and control in competitions for FIRST. Finally, Joseph is a skilled chess player, competing in regional tournaments around the Mid-South.

Endnotes

1. http://www.arrl.org/single-band-dipoles
2. https://commons.wikimedia.org/wiki/File:Antenne_gp_vhf_3.jpg (CC BY-SA 3.0)
3. http://www.wirelessinnovation.org/assets/documents/SoftwareDefinedRadio.pdf
4. https://www.nuand.com/blog/product/bladerf-x40/
5. https://www.nuand.com/blog/product/amplifier/
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8. http://www.hardkernel.com/main/products/prdt_info.php?g_code=G143452239825&tab_idx=1
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