To the Editor: Content highlighted in grey are directives to you.

[Preview]
What do you do when there's no cell service, but you need to contact someone far away? The current market for off-grid communication systems is missing an affordable, user-friendly option, so three Camosun College students created just that. FloraNet is a battery powered and accessible network that uses LoRa radio to keep people in touch in the back country.

[Article Start]
We are Flora Communications, a group of three Electronics and Computer Engineering Technology students at Camosun College. For our capstone project, we've built an alternative off-grid communications network called FloraNet using LoRa Radio. FloraNet is a pre-installed network that operates on battery and solar and does not require an internet connection or cell service. FloraNet is designed to be as user-friendly as possible, accessed via web browser through a JavaScript and HTML web app served by an ESP32-S3 microprocessor over a locally hosted Wi-Fi connection. Users can post messages to the public network chat and contact emergency services directly from their smartphone without needing a user account, pre-installed app, or additional hardware.

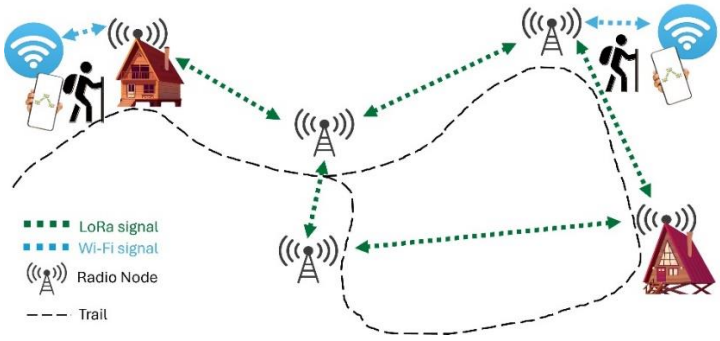

Figure 1
Type: *Image*
Source: *FloraNet.jpg*
Caption: *FloraNet is made up of Petal Radios that send messages using LoRa radio using our firmware and provide a user-friendly interface using a locally hosted Wi-Fi network and custom web app.*

Good Products and Great Products
We believe that a good product is well-designed and useful, but a great product is well-designed and useful *for everyone*. As inventors and enthusiasts, it's easy for us to lose sight of three main barriers to a product being widely adopted and useful for a customer base: complexity, cost, and the customer themselves. Requiring the customer to navigate the seemingly endless options on the market can overwhelm them. Having them pay for another subscription or upgrade can be frustrating, even if it's the best or only option available to them. Even the most useful product won't be adopted if the customer feels inconvenienced by the user interface or the setup requirements. The average customer is more prone to these pitfalls than someone who is passionate about the product or technology. As both technology and outdoor enthusiasts, we saw that the off-grid backcountry communication market is missing a *great* product.

FloraNet targets outdoor recreation areas outside of cell service that see a high volume of casual visitors, such as ski resorts, national parks, or popular hiking trails. Organizations that maintain these places (resort operators, recreation departments, outdoor clubs, etc.) can install a network of the Petal Radios we

designed (also referred to as *nodes*), scattered throughout the desired coverage area every few hundred to thousand metres, depending on the terrain.

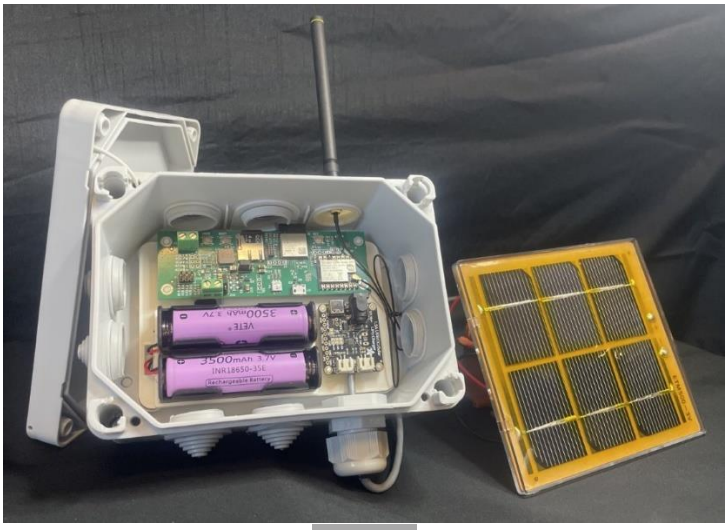

Figure 2
Source: *petal-node.jpg*
Type: *Image*
Caption: *A Petal Radio node with the Petal Radio, enclosure, LoRa antenna, solar panel, charge controller, and battery pack on a custom 3D-printed backing plate. In a real installation, the enclosure would be waterproof, and an external activation button would be wired to the Petal Radio through a cable gland.*

Visitors can go to a Petal Radio node and press the button to activate it. Using the smartphone already in their pocket, they connect to the FloraNet Wi-Fi network and scan the QR code on the node. This brings them to our intuitive messaging web application in their browser where they can send and receive messages with other Petal nodes or emergency services using LoRa ("Long Range") radio. FloraNet is a completely off-grid and user-friendly wide area communication solution that works with any smartphone, installed for a fraction of the cost of a cell network upgrade.

Mrs. Patagonia & Mr. Denim
We'd like to introduce you to the FloraNet brand ambassadors, Mrs. Patagonia and Mr. Denim! Born and raised in Victoria, British Columbia, Canada, Mrs. Patagonia is an avid outdoors enthusiast and skier. She is always prepared for anything in the back country. Mr. Denim had humble beginnings in the flatlands of Manitoba, where the largest hill in his childhood town was hardly larger than the stairs to his bedroom. He moved to Victoria in his early twenties where he met Mrs. Patagonia, but she has always been the "outdoorsy" one.

Figure 3
Type: *Image*
Source: *patagonia-denim.jpg*
Caption: *Always-prepared Mrs. Patagonia and her laissez-faire husband Mr. Denim.*

For their 20th wedding anniversary, Mrs. Patagonia has convinced Mr. Denim to try his hand at skiing with an all-inclusive, powder-filled week at Mount Washington Ski Resort, a three-hour trip north of Victoria. Despite his altitude-free upbringing, Mr. Denim quickly picks up skiing and is shredding black diamonds in no time. On the last day of the trip, the couple decides to try a run through a glade of trees off the beaten path. Mr. Denim quickly realizes he's out of his element, but he decides to tough it out… CRACK! One ski goes left, the other goes right, and his ankle is on fire. Mrs. Patagonia stops next to him in a shower of powder, but she can tell they're in trouble. Mr. Denim can't move his right foot without whimpering in pain. She checks her phone, but there's no cell service in the shadow of the mountain. If this was in the back country, she'd have an emergency satellite transponder, but she didn't pack it because she figured there would be service. She's confronted with two possibilities: leave Mr. Denim alone and injured in the snow while she skis down to fetch ski patrol, risking her own safety in the process, or stay with him and hope someone happens to ski by them in this thick, dense forest. This is where FloraNet would save the day.

Mrs. Patagonia's Current Options
If Mrs. Patagonia doesn't want to stray too far from Mr. Denim but still contact rescue services, the current options on the market are a satellite transceiver device like the Garmin InReach or a mesh network like Meshtastic.

Satellite Transceivers
Satellite transceivers like the Garmin InReach are handheld devices that provide full coverage anywhere in the world.

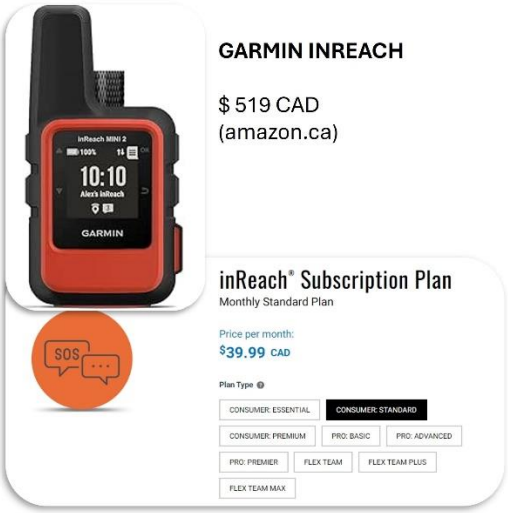

Figure 4
Type: *Image*
Source: *inreach.jpg*
Caption: *Garmin InReach satellite transponder and the associated subscription services.*

Users can send and receive text messages to phone numbers and other InReach devices or press the SOS button to send their GPS location to the Garmin Response Center in Texas where they'll coordinate a rescue with the emergency services closest to your location. These devices are highly effective but terribly

expensive. Their upfront cost can be up to $700, plus a monthly subscription to access the satellite network. Because rescues are coordinated by the Garmin Response Center, rescues take a lot longer compared to contacting search and rescue directly with a cellphone. For the hardcore outdoors person, this cost is worth it, and it works well if the user remembers to charge and pack it with them. Although Mrs. Patagonia has an InReach for her more intense backcountry hikes, she didn't think to bring it to a ski resort where she assumed ski patrol would be everywhere. Satellite transceivers are a good product for the hardcore adventurer, but their high cost and the annoyance of bringing another device means they aren't good for everyone or every situation.

DIY Mesh Network

Another option is a mesh network like Meshtastic, an open-source digital radio enthusiast project that provided us with the inspiration for FloraNet. Like FloraNet, a Meshtastic network is made up of Meshtastic devices that communicate using LoRa radio. Each device is a node that users can send text messages from.

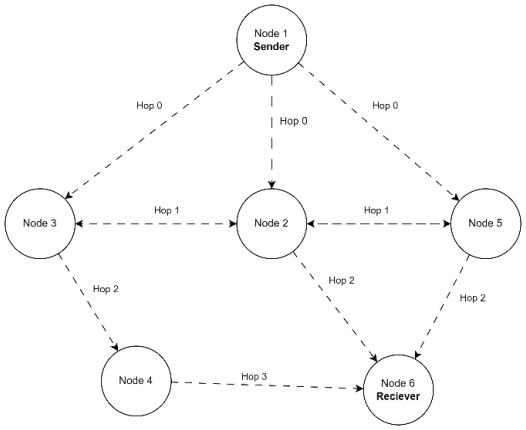

Figure 5
Type: *Image*
Source : *mesh-hopping.jpg*
Caption : ***Error! Reference source not found.****: A message from Node 1 to Node 6 "hopping" through a mesh network. Each message re-broadcast is labelled with a hop number.*

The user connects to the device with their smartphone via Bluetooth using the Meshtastic app from their app store. In the app the user can configure the device and exchange text messages with other nodes. When the user presses send, the text message is broadcast using LoRa radio. Any nodes nearby that receive the message will then repeat the message. The message will "hop" from node to node through the mesh network until it reaches its desired destination. Users can purchase a Meshtastic-compatible device for as low as $15 and set it up using the guide on the Meshtastic website.

While Meshtastic is cost-effective, its not a perfect replacement for a satellite transceiver. They only work when all users have a Meshtastic device and the app pre-installed. Moreover, device setup and configuration requires a decent amount of tech savvy and digital radio knowledge. The complexity of device configuration and the inconvenience of needing both a smartphone and a LoRa device has prevented Meshtastic from becoming a viable option for the average consumer.

Please place the following section as a highlighted side bar as a sort of "FYI" explaining how LoRa works

LoRa is a low power, long range digital radio technology that is mostly used by Internet of Things sensors to send data to a master controller. LoRa sends digital 1's and 0's over the airwaves in the 915MHz ISM band in North America. Lora uses a special way of encoding the digital data (called *modulation*) that uses less power and has a longer range than cell service or Wi-Fi. This is perfect for battery powered devices in outdoor situations. The trade-off is a much lower throughput, between 90 bits per second and 20 kilobits per second depending on the desired range, so LoRa only supports text messages up to 255 characters long.

End of LoRa FYI Section

FloraNet Ticks All the Boxes

FloraNet attempts to fill the niche between Garmin InReach and Meshtastic for the casual outdoor adventurer in the places they visit the most. If the ski resort had FloraNet installed, Mrs. Patagonia could go to the nearest Petal Radio (a few hundred metres away at most) and send an SOS message to ski patrol using the smartphone already in her pocket. Based on the node she sends her messages from, ski patrol would know where she is, and she can stay with Mr. Denim until they arrive. The rescue response time will be much faster than if she used a satellite transceiver or if she had to ski back to the resort to flag ski patrol down. FloraNet moves the cost of emergency communications from the individual to the community in popular recreation areas, can be accessed by anyone who knows how to connect to a Wi-Fi network, and doesn't require a separate device, user account, or pre-installed third-party app.

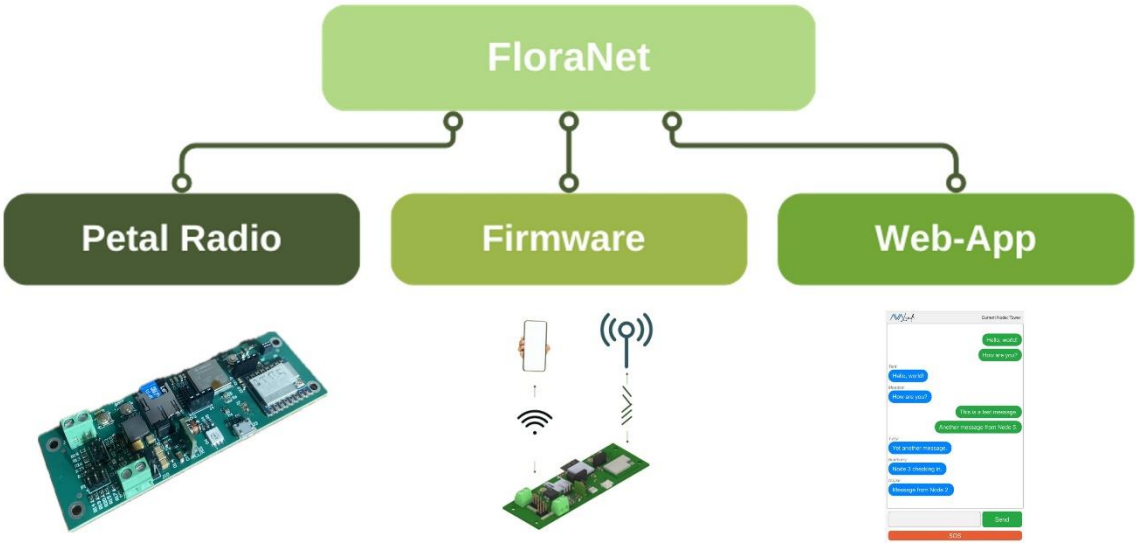

Figure 6
Type: *Image*
Source: *hierarchy.jpg*
Caption: *FloraNet is made up of the hardware we designed called the Petal Radio, the firmware we wrote using FreeRTOS, and the web app we created using JavaScript, HTML, and CSS.*

Bringing FloraNet to Life

Starting in September and finishing in December of 2024, we worked seven days a week to bring FloraNet to life. We started by creating a requirement specification sheet to guide our work. The first major task was designing, assembling, and testing the Petal Radio PCB. We then coded custom firmware

for the Petal to interface between the web-based user interface and the rest of the LoRa mesh network. In the meantime, Cameron learned JavaScript, HTML, and CSS web development over the course of a month to build our intuitive messaging web app from scratch. We've made the hardware files and the code available through our **Text:** GitHub **Hyperlink:** https://github.com/flora-comms/flora-comms, along with a Wiki you can read to learn how to set up your own network using the Petal Radios.

Petal Radio

Petal Radio is the PCB prototype for our project. We wanted a board that would work reliably so we could focus on developing firmware and software. It has primary and backup power supply units (PSUs), a microprocessor unit (MPU), and a LoRa transceiver module. We designed it in Altium Designer with feedback from our professors and had it manufactured by JLC PCB in China.

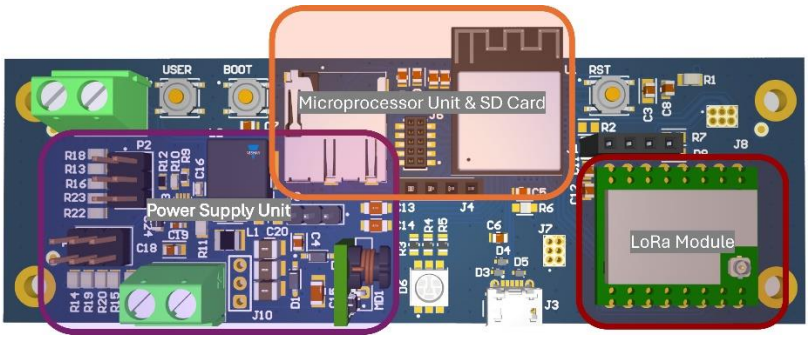

Figure 7
Type: *Image*
Source: *petal-layout.jpg*
Caption: *A 3D rendering of the Petal Radio with important sections highlighted and labelled.*

Power Supply Unit

Since the Petal will run on battery power in the field, we prioritized efficiency when selecting a power supply. We also wanted a low voltage disconnect (LVD) to protect the battery from excessive discharge. We included both a primary and backup PSU, and our testing pitted these two against each other to determine the best option for future versions.

The primary PSU is a Texas Instruments TPS62933P switching power supply IC. Based on our research, this PSU is relatively cheap, offers the highest efficiency, and has a built-in LVD. It can handle anywhere from 3.8V to 30V input with a 3.3V output. The only drawback was that we had to design the complex buck converter and electromagnetic interference filter circuitry around the IC. If our power supply design was faulty, this would render our board useless and prevent us from testing our other circuitry, so we included a backup PSU.

The backup PSU is a Texas Instruments TPSM84203EAB switching power supply module. It is more expensive than the primary and does not have a built-in LVD, but it comes with all the circuitry pre-assembled on the module, so it is plug-and-play with three through-hole pins.

We tested both PSUs for efficiency, ripple voltage, and transient load response. We were happy to see that the primary PSU circuit we designed beat out the prefabricated model in all our tests, and the LVD circuit worked better than expected.

Microprocessor Unit

We chose an ESP32-S3-MINI module for our MPU. It is a dual core 240MHz processor with a built-in Wi-Fi modem and antenna that can act as a Wi-Fi access point (AP). It has an active developer community with plenty of open-source libraries available on GitHub for embedded applications, and its sleep routines and power consumption capabilities lead the industry for battery powered devices. It interfaces with our LoRa module and an SD card through two separate SPI busses and serves the web application using our firmware. The SD card is on the board to hold the web application files and chat history logs that are too large to hold in the processor's internal flash memory. Having a removable SD card also makes it easy to test and modify the web application files without reprogramming the firmware. The MPU is programmable through a micro-USB port, but we also included pin headers for the UART serial pins in case the USB port doesn't work. The MPU is the heartbeat of the Petal Radio.

LoRa Module

The LoRa module we chose is the WAVE-Core1262-HF module from WaveShare Electronics. It uses the Semtech SX1262 LoRa transceiver for the 915MHz ISM band in North America, which is the current industry standard for IoT LoRa devices. Because RF PCB design requires money and time (two resources we don't have), we used a module that included the necessary RF circuitry despite being more expensive than designing the circuit ourselves. It communicates with the MPU using a SPI bus. The LoRa module interfaces the Petal Radio with the rest of the mesh network.

Firmware

The firmware has three main responsibilities: serving the web application, interfacing with the LoRa mesh network, and managing the device's power consumption. We wrote the firmware in C++ with FreeRTOS, a common embedded operating system, using the PlatformIO Arduino development framework in VS Code. Each responsibility is a *task,* meaning FreeRTOS can run these processes *asynchronously* (independently) of each other. FreeRTOS also provides *queues* and *event groups*, which are methods for tasks to communicate with each other and cooperatively share memory. We use queues to pass messages from the client and mesh network between the tasks and an event group to signal the state of tasks and peripheral hardware. The FreeRTOS kernel provides all the tools we need for FloraNet.

The web server task provides the user interface to the client. To serve the web application files from the SD card, we used the popular *ESPAsyncWebServer* library from GitHub user *me-no-dev*. When the activation button on the Petal is pressed, the firmware turns on the Wi-Fi network for the user to connect to. When the user connects and scans the QR code or navigates to *floranet.local* in their browser, a DNS server spins up an AsyncWebServer instance and serves the JavaScript, HTML, and CSS from the SD card using HTTP. The client JavaScript upgrades the HTTP connection to a WebSocket, allowing communication in both directions between the client and server. The web server receives messages sent by the client and passes them to the LoRa task using a communication channel called a *queue* provided by the FreeRTOS kernel. It also receives incoming messages from the LoRa task through another queue where it updates the client interface. The web server task is the gateway for the user to the rest of the network.

Figure 8
Type: *C++ code*
Source: *main.cpp*
Caption: *FloraNet initialization code starting the web server, LoRa, and power management, tasks.*

The LoRa task sends and receives messages between the client and the rest of the network. After receiving a message through the queue from web server task, it does some checks to prevent the Petals from talking over each other before creating a 255 byte packet and sending it to the LoRa module for

transmission. When not transmitting, the firmware puts the LoRa module into receive mode. Upon receiving a message, the firmware checks that the message hasn't been heard previously and re-broadcasts it if necessary. The LoRa task makes the mesh network robust and reliable.

The power management task monitors the web server and LoRa activity and decides when to put the MPU to sleep to save power. Transmitting a Wi-Fi signal draws a significant amount of power, so when no one is around, the Wi-Fi should be shut down to conserve power. The power management task monitors the web server activity, and turns off the web server and Wi-Fi AP after five minutes of inactivity. The firmware puts the Petal into a light sleep mode, power consumption over 90%. When the activation button is pressed or the LoRa module receives a message, the power management task will wake the processor up and signal the appropriate task to deal with the wake-up event. Messages received during sleep are stored on the SD card for the next time the web app is requested before continuing through the mesh network. The power management task greatly improves the Petal's efficiency, saving money with smaller batteries and preventing outages caused by power loss.

Web App

Our web app is a user-friendly messaging app written in vanilla JavaScript, HTML, and CSS where users can post messages or SOS alerts to a public chat box visible to all Petals on the network. Our layout was inspired by common SMS messaging platforms so that the functionality would be intuitive for the user. The top right corner shows the user which Petal they are connected to. The sent and received messages are displayed on the screen in the order they are received, with messages sent by the node the user is connected to on the right of the screen in a green bubble, and messages received from other nodes on the left in blue bubbles. Each message is stamped with the node they came from. Along the bottom of the screen, there is a text box to enter messages into, a green Send button, and a large SOS button. The familiar and simple layout means that our web app should be accessible by anyone, regardless of language, in an emergency.

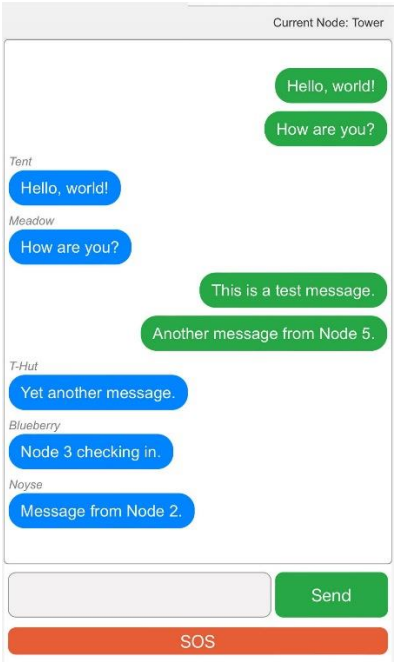

Figure 9
Type: *Image*
Source: *web-app-layout.jpg*
Caption: *The FloraNet messaging web app rendered on a smartphone using Safari browser.*

True Product Value

Petal Radio, the firmware, and the web app were designed with the customer in mind, aiming to reallocate cost from the individual to the community, minimize product complexity, and facilitate customer adoption, all while providing a useful service. If you are an inventor, we hope FloraNet inspires you to remember who you invent and innovate for. If you are an enthusiast, we hope FloraNet reminds you what you should expect from the companies that push the boundaries of technology.