Design Factors of 5G Bringing Innovation to the Medical Field

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***Abstract*—The medical field is a ever growing, vastly changing sector of our culture. Technology has a direct impact on its growth thus causing the rapid evolution of this aspect of our economy and truly innovating this field in its entirety. We asked ourselves, "Is there a better way to utilize 5G than incorporate it into the medical field?" Many healthcare providers rely on numerous electronic devices to provide pertinent, critical information about the patients. More recently, many of these devices have transitioned from analog to digital and have incorporated the capability of remote monitoring due to the use of wireless and Bluetooth technologies. Based upon this knowledge, we brainstormed the idea of utilizing the 5G network to enhance the transmission of data. 5G Cellular has increased bandwidth capabilities and faster upload and download speeds, directly impacting the speed at which much needed accurate data could be received. Our project hopes to use 5G cellular along with 5G LAN integration to connect healthcare providers with individuals or patients and their caregivers to enhance their ability to send and receive pertinent data in a rapid, seamless, fashion. 5G cellular will tremendously enhance the capabilities of that equipment. This can only be achieved if there is seamless coverage inside and outside of our entire nationwide footprint. We wish to explore the underling technology that makes 5G NR (New Radio) so amazing. 5G cellular has issues traveling thru building structures. Because of this, there needs to be a way to fully integrate 5G LAN so that it works hand in hand with 5G cellular, in order to provide seamless communication for the mobile devices that we are exploring to work seamlessly both inside and outside.**

***Index Terms*—5G cellular, 5G LAN, Small Cell Networks, Femtocells**

I. Introduction

Imagine wearing a device that could inform you of an impending medical emergency. 5G cellular technology has the potential to allow devices such as this to exist and do much more. 5G has the potential to help healthcare organizations with a high demand of IoT focused transformations, for example"Fig. 1. 5G in Healthcare 1. Like with all new technologies, 5G has some obstacles to overcome. For instance, it does not travel well through. Additionally, there does not seem to be one agreed upon standard for the new technology. Large communication companies like Verizon are rolling out their own versions of 5G LAN and wireless systems. These systems are in their infancy. They are still being developed and tested so there is not a lot of technical data available about them but it is coming rapidly. We appear to be on the cutting edge of a new revolutionary technology! According to "Market Watch", the global investment in Internet of Things (IoT) from

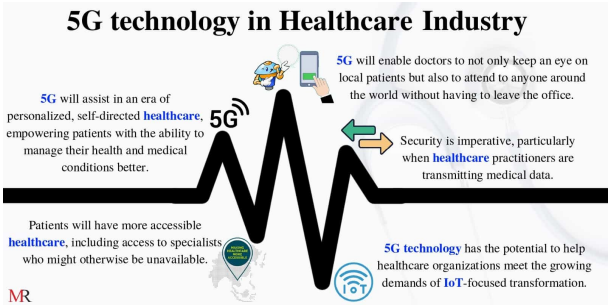

Fig. 1. 5G in Healthcare

the medical industry should reach 410 billion by 2022! That figure will keep on growing exponentially in the near future and according to statistics, much of that investment will come directly from IoT markets. [1] "The 3rd Generation Partnership Project (3GPP) unites [Seven] telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as "Organizational Partners" and provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies [2]."

II. Background

A. The Evolution of Broadband

5G is an exciting, new, trending technology that has the potential of changing the landscape of virtually everything we do in our day to day operations. The capability of having Gigabyte speed on the fly is tremendous. First responders will be able to send pertinent, life-saving data to medical personnel prior to the arrival of emergency vehicles in real time enabling them to better triage and deliver care in an unprecedented fashion. Fire fighters will be able to scan structures in real time and provide feedback to the command center. These changes can be significant and can be measured as being as dramatic as the evolution of transportation from horse and buggy to space flight. The evolution of data for Small Office Home Office,(SOHO), users occurred rapidly. It began with dial-up modems with a maximum bandwidth of 56Kbs in the mid 90's. This quickly gave way to Integrated Service Digital Network, (ISDN), which offered a maximum speed of 128Kbs in the late 90's and early 2000's. Asynchronous Digital Subscriber Lines, (ADSL), provided speeds up to 768Kbs initially, then

5G NR (5G1) Operating Bands Sub-6 GHz					
NR Operating Band	Uplink (MHz)		Downlink (MHz)		Duplex Mode
	FUL_low	FUL_high	FDL_low	FDL_high	
n1	1920	1980	2110	2170	FDD
n2	1850	1910	1930	1990	FDD
n3	1710	1785	1805	1880	FDD
n5	824	849	869	894	FDD
n7	2500	2570	2620	2690	FDD
n8	880	915	925	960	FDD
n20	832	862	791	821	FDD
n28	703	748	758	803	FDD
n38	2570	2620	2570	2620	TDD
n41	2496	2690	2496	2690	TDD
n50	1432	1517	1432	1517	TDD
n51	1427	1432	1427	1432	TDD
n66	1710	1780	2110	2200	FDD
n70	1695	1710	1995	2020	FDD
n71	663	698	617	652	FDD
n74	1427	1470	1475	1518	FDD
n75	N/A		1432	1517	SDL
n76	N/A		1427	1432	SDL
n78	3300	3800	3300	3800	TDD
n77	3300	4200	3300	4200	TDD
n79	4400	5000	4400	5000	TDD
n80	1710	1785	N/A		SUL
n81	880	915	N/A		SUL
n82	832	862	N/A		SUL
n83	703	748	N/A		SUL
n84	1920	1980	N/A		SUL
n86	1710	1780	N/A		SUL

Fig. 2. Operating Bands

Non-standalone 5G New Radio Waveform and Sub-Carrier Spacing				
Generation	UE Transmit Waveform	Modulation	Channel Bandwidth (MHz)	Sub-Carrier Spacing
4G	SC-FDMA	QPSK, 16QAM, 64QAM, 256QAM	5 to 20	15 kHz
5G1 (FR1)	DFT-S-OFDM	π/2 BPSK, QPSK, 16QAM, 64QAM, 256QAM	5 to 50	15 kHz
	DFT-S-OFDM	π/2 BPSK, QPSK, 16QAM, 64QAM, 256QAM	5 to 100	30 kHz, 60 kHz optional
5G2 (FR2)	CP-OFDM	π/2 BPSK, QPSK, 16QAM, 64QAM, 256QAM	5 to 50	15 kHz
	CP-OFDM	π/2 BPSK, QPSK, 16QAM, 64QAM, 256QAM	5 to 100	30 kHz, 60 kHz optional

Fig. 3. 5G Standalone

up to 3Mbps in the mid 2000's. Emerging bonded cable pair and Fiber optic technologies pushed bandwidth from 15-30Mbps with BPON, (Broadband Passive Optical Network), in the mid 2000's to 100Mbps by 2010.GPON, (Gigabyte Passive Optical Network), increased the capability of fiber optic systems to Gigabytes speeds. All of the prior mentioned technologies have one thing in common, they all emerge from a known, established Demarcation point, (Demarc), also known as the MPOP, (Minimum point of Penetration). 5G, on the other hand, typically does not originate from a pre-established demarc and there is not much, if any, information described in demarcation processes or stand installation procedures for this new technology. Our goal is the establishment and development of the demarcation of this new technology.

The evolution of broadband communications is astounding. The technology has changed drastically since its initial inception. 2G, 3G and 4G cellular services were initially designed for and dedicated to mobile broadband. The network infrastructure was primarily designed for urban and rural usage with less resources dedicated to rural configurations. 5G, on the other hand, has loftier goals. See Figure 2 [3]. Its enormous bandwidth and extremely low latency will allow a broader array of applications functionality. Legacy GSM, Global System for Mobile Communication, Networks operated between 850 MHz and 1900 MHz. 2G and 3G networks use the same frequencies. They differ only by the modulation method used to deploy the services. The CDMA, Code-division multiple access, method of modulation uses the same frequencies for 2G as the legacy generation while WCDMA, Wide-band Code Division Multiple Access, adds 2100MHz for 3G. The frequencies of 600 MHz, 700 MHz, 1.7 GHz, 2.1 GHz, 2.3 GHz and 2.5 GHz were all added with the iteration of 4G LTE. 5G frequencies differ tremendously in spectrum allocation as well bandwidth. The frequency spectrum for sub-6 GHz ranges from 450 MHz to 6 GHz. The 5G allocation also includes the millimeter wave frequencies of 24.250 GHz to 52.600 GHz as well as an unlicensed part of the spectrum. 4G bands are assigned the spectrum allocation of between 5 MHz and 20 MHz of bandwidth. The peak speed of 4G in most urban areas is 10 MBPs with a latency rate of tens of milliseconds. 5G bands are divided in to two groups, the sub 6GHz band which is everything below 6 GHz and is inclusive of the entire 4G network and the millimeter wave group, which start at frequencies over 30 MHz as well as a second frequency group with a range of from 24 GHz to 52 GHz. 5G bands range from 5 MHz to 100 MHz of bandwidth per channel which is an increase of five times the bandwidth. [3] The peak speeds can be as high as 20 Gbps See Figure 3 [3]. The average rate for an urban area is 100 Mbps with a latency as low as 4 milliseconds. 5G is the 5th generation of mobile networks and has nothing to do with 5 GHz WIFI. 5 GHz WIFI is WIFI that operates at the 5 GHz frequency. The higher frequencies allow more throughput.

B. Small Cell Technology

The transition from 4G to 5G technology is an interesting topic. Many wonder why we even need to change the status quo. Although change is not always bad, some people tend to linger on the thought process of "if it ain't broke, don't

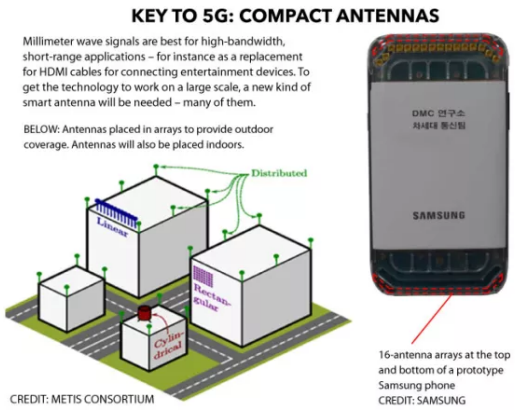

Fig. 4. Multi antennas

fix it". Many have even asked "why are we even changing to this 5G thing"! 4G is not capable of sustaining the network presence or bandwidth required to sustain the (IoT)1, Internet of Things and it will not allow them to maintain their full functionality or their full range of capability. The significant difference between the two is the capability of 5G to function via a network array of distributed active and passive antennas. The antenna networks are classified as small cell, macro cell, radio access network (RAN), and distributed antenna network (DAS). The antenna type and network type are determined by the communication infrastructure used by the supplying entity which are mostly the last mile providers ATT and Verizon.

5G networks will enable enhanced mobile broadband services with higher data rates, lower latency and more capacity, as well as new use cases that will generate additional revenue streams for the operators. The ability to handle multiple, tailored use cases is what makes 5G more exciting than previous versions of mobile technology. Telecom vendors and parties involved in deploying 5G technology should make sure that the new technology is backward compatible with 4G and older cellular technologies. The key here is to create a win-win scenario where 5G works alongside the current 4G services as we slowly transition to faster and improved services. Managing the available spectrum between the 4G and 5G will be crucial for the better development of future 5G services. Since faster speeds is one of the key selling points with 5G, telecom operators should take advantage of exiting 4G hardware and build a platform where 4G and 5G will co-exist and leverage it to gradually upgrade the services to 5G standards starting with the cell sites and antennas. See Fig 5 [4].

Femtocell, Picocell, Microcell, and Metrocell are all types of small cell networks. [5] Femtocells are the smallest of the small cell devices and use the least amount of power See fig. 4 [5]. Femtocells are used to extend network connectivity to SOHO applications and are powered and connected directly by the end user. Picocells are small base stations as well that are deployed in places like office buildings and shopping malls. They differ from Femtocells in that they are managed and configured by a network operator who pays for the connection

Small Cell Type	Cell Radius	Power Level (Watts)	Number of Users
Outdoor DAS (oDAS)	1 mile	20	3,000 per sector
Indoor DAS (iDAS)	Up to 200 feet per antenna	2	2,500 – 3,000 per sector
Microcell	1 mile	10	1,800 per baseband unit
Metrocell	500 – 1,000 feet	5	200
Picocell	750 feet	1	32
Femtocell	50 - 60 feet	0.1	4 - 6
Wi-Fi	50 - 60 feet	0.1	Up to 200 per access point

Fig. 5. Small Cell Network

to the network and the resources required to operate the device. The Microcell is another low power cellular base station. It differs only slightly from the Picocell in its coverage area which is controlled by the amount of power given to the device [6].

Metrocells are deployed to fill in gaps in coverage within buildings. Metrocells are much like femtocells because they have been successfully deployed in SOHO configurations but differ by offering expanded capacity and coverage range. They are capable of having 16 to 32 subscribers at a range from less than 100 meters to several hundred meters depending on the environment. Metrocells are high- capacity but utilize very low power to accomplish their goal. Macrocells are the legacy high power base stations. They have a range of 20 miles.

A C-RAN is a relatively new concept. C-RAN combines the signal from multiple radios deployed throughout a large building by processing them into a single, seamless cell. A DAS is composed of a network of small radio heads placed in a strategic configuration throughout a specific location, such as a large venue, to significantly increase the cellular bandwidth for an event without overloading the existing cellular tower. Each radio head is directly connected to a hub by fiber optic cable. The hub is then connected to a cellular base station which performs the routing and processing of data [7].

C. Commercialization of 5G will focus on three topics

- Enhanced Mobile Services
- Integrating IoT devices into 5G services in a massive scale
- Integrating Critical Services into 5G services
  The key here to use existing LTE technology as a road map to 5G. This process will enable parties involved to iron out issues as they arise from the daily use. This can range from software to hardware to Cybersecurity. Another element to consider is that 5G services should be backward compatible with LTE and the IoT devices currently in use.

D. Diverse Needs of IoT Applications

- Mobile Health Wearable Gateways, with Remote Patient Mobile Health wearables can keep patients remain safe from potential life threatening issues by sending vital information to the nearest health care provider. Doctors

can keep track of patients health remotely using IoT and 5G services.

- Tele-health Benefits. Quickly Transmitting Large Files and Better Viewing: There are many rural and remote areas. Over 5 billion people in our population don't have the correct healthcare resources. 5G can enable for doctors to be able to view high quality images and files of a patient. Remote diagnosis can be a thing of the future with the help of 5G. Reliable, Real Time Remote Monitoring Utilizing IoT devices, healthcare providers can monitor patients and gather data used to improve overall health. 86 percent of doctors say that wearable devices increase patient engagement with their own health. To make it even better, wearable devices are predicted to decrease hospital costs by 16 percent in the next 5 years.
- Ubiquitous Coverage
  Ubiquitous coverage can be accomplished by using both 5G and 4G along with backward compatible services to provide continuous mobile coverage
- Smart Cities Lighting, via the use of Traffic Sensors, and Smart Parking
  Utilizing 5G with Machine Learning and IoT, we can reduce our carbon foot print by burning less fossil fuels to managing traffic on the streets.
- Connected Building Security, Video Surveillance, and Smoke Detectors
  Keeping the public safe using IoT can save lives. From video surveillance to smoke detectors, IoT and 5G raise the bar in our day to day living standards.
- Asset Tracking Fleet Management, Pet/Child Trackers, Shipping
  Why pay for satellite services when you can track your trucks and packages using IoT devices with 5G.
- Entertainment to Concert fans. Attach an IoT device (hand band) to the concert fans and let them feel the music like they never felt before [1].
- First Responders, AR Firefighter helmet. While researching all types of possible devices, we came across a device that can be used with firefighters. No more will a firefighter have to crawl along the floor and keep one hand touching the wall because the room is full of smoke. Before now firefighters relied on thermal imaging camera to navigate hot spots. The use of a thermal imaging camera does not have a live view and the firefighter would have to stop to review the image, also loose the use of one hand to operate the camera. A company called Quake has developed the AR firefighter helmet which uses a system they call C-THRU. This system combines thermal imaging, toxicity sensors, and edge detection built into an OBA with selective noise cancellation for better communication. The system as it is designed now connects with a control device located outside. I believe that with 5G cellular integration this device could become more mainstream and eventually more affordable [8].

Solution	Description	Technology	# Users	Cell Radius
DAS	Typically fed by a macro or micro base station. High power, multi-frequency, multi-carrier.	UMTS HSPA+ LTE	Up to 1,800 users per base station	Up to 3 miles
Wi-Fi	A wireless access point connects a group of wireless devices to an adjacent wired LAN.	802.11b 802.11g 802.11n	Up to 200 users per a 3-radio access point	65 feet
Microcell	Short-range base station used for enhancing indoor and/or outdoor coverage.	UMTS HSPA+	32 to 200 users	Up to ≈1 mile
Metrocell	High-capacity, low power device that fills in coverage holes within buildings.	UMTS HSPA+	16 to 32 users	10,000 – 20,000 square feet
Picocell	Typically used for indoor applications such as office buildings, airports, and malls.	UMTS	32 users	Up to 750 feet
Femtocell	A small, low-power cellular base station typically used for a home or small business.	UMTS	4-6 users	40 feet

Fig. 6. Data transmission distances

III. Literature Review

Using 5G with Wireless Body Sensory Network along with IoT and Smart Mobile

Here we look at mobile health care utilizing IoT devices and 5G. This technology carries great potential in several areas. Mobile health care using 5G can reach far off places where health care services are basically nonexistent. Doctors and nurses can diagnose and monitor patients connected via IoT devices utilizing Wi-Fi, ZigBee or Bluetooth tied to a 5G Smartphone, for example see Fig 6 [6] . This reduces the amount of time needed to triage a case. Additionally, it allows the health care providers more flexibility in the decision making process as well as the application of treatment and the implementation of care plans thus providing better patient care and a significant uptick in the level medical services provided. This has the capability of being a game changer in 3rd world countries. Doctors and nurses can share patient info on how to provide better care from their finger tips. [9]

In order to fully understand 5G, we will need to break it down and explain every aspect possible. Citing Amy Nordrum's article, "5 Myths about 5G", in which she talks about the various types of information that has been collected about 5G technology. For starters, she touches upon the fact that experts have said 5G will be the future's 'hot spot' system. The concept behind it is that 5G will be deployed over small cell networks and comparing to a traditional cell tower that broadcasts signals indiscriminately, it will have single base stations that will be on rooftops and lamp posts that will act as hyper-local areas. The big problem behind this is that labeling 5G as a hot spot system at such an early part of it's life, it's closing itself to future innovations. Another big concept that we wanted to clarify is "5G will replace 4G". Many people think that 5G is going to get rid of 4G completely and that it will act as our sole network. This goes back to 2G and 3G, which are still utilized around the world. Even though 5G and its entities may revolutionize things, there are various cases that say that 4G is more useful in that situation. Although 5G is going to be leading, 4G isn't going anywhere anytime soon. The positive side of 5G that is referenced in the article is that 5G might not need substantial investing to make it

widespread. She states that, "5G will be deployed on existing infrastructures." [10] Capital expenditures are expected to drop when 5G is deployed as predicted by the roll out of LTE, which caused no influx in Capital. [10]

IV. Methodology

A. 5G Devices

Now that we have broken down what 5G is and how beneficial and leading edge it is going to become, we will concentrate on expanding upon how we plan on incorporating it. As mentioned previously, technology in the medical field has been quite leading edge, and it will continue to grow as time goes on. Here are a few technical requirements to take into consideration:

- 2 way secure communications via 5G/4G/3G/WiFi
- Voice activated or Touch button feature to initiate / end a call
- Wearable device will monitor all major vital signs,along with location detection via GPS or available mapping software
- The hub unit with multiple sensors will monitor in-home air quality, will detect pathogens in the air, and room temperature
- The wearable unit and the hub have built-in video cameras
- Both units are compatible with GSM/CDMA technology
- The hub unit can be placed on a table or mounted to the wall
- The hub includes a battery backup system
- Software is compatible with Android phones
- Artificial intelligence is embedded on the hub via a chip to learn and monitor patient's day to day routines and health in general.

5G service has huge potential to innovate and transform preventative, routine and post-operative patient care by utilizing real time features. Telecom and health care operators will have the advantage of 5G technology to pursue tel-medicine, precision medicine and online consultations. Chronic health issues and medications can be managed via apps on the phone. The eHealth aka Electronic Healthcare is at the cross roads pertaining to the exploration of the capabilities of 5G in real-time services. The distinguished solutions will utilize IoT, real time monitoring, cloud services, 5G and other services to manage and provide better continuity of healthcare. Wearable patches can include biosensors that will monitor the heart rate, blood pressure and oxygen saturation. Since these devices provide real-time monitoring the reliability of information is paramount that require proper attention. The key word we should be looking for is error free reliable data.

B. Fog Computing

The term "Fog Computing" or edge computing originated from Cisco See Fig. 7 [11]. Cisco coined the term fog computing to differentiate data stored and processed in the cloud compared to the data stored closer to the ground. [11] Fog Computing has its roots deeply embedded in Cloud

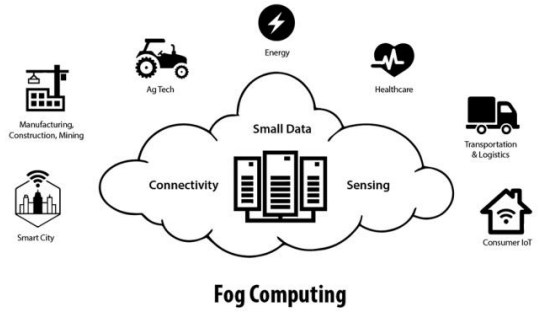

Fig. 7. Fog Computing

Computing. The idea is to strategic placement of data, i.e. services and applications between the source and the cloud, reducing the distance between the cloud and the end device results in improved application responsiveness, network performance and overall efficiency. Fog Computing presents the opportunity to analyze data based on priority. Time sensitive data is displayed at the console while non-critical data is queued up in the cloud waiting to be analyzed. This type of computing platform is most suitable for IoT devices. Since IoT devices are mostly real time devices, Fog computing can be a perfect partner in collecting, prioritizing and processing data. With billions of IoT devices generating data constantly, a new kind of infrastructure is needed to tackle the vast amount of information. Let's examine the criteria below:

1. Design a network with very low latency, high reliability and security
2. Build cutting edge applications for Fog Computing
3. Configure the priority on data that needs to be analyzed
4. Segment your network so that data collected will be easy to identify and process
5. Train end users so they are prepared to manage the network, devices and data.

C. How Fog and Cloud Process Data

Fog IoT devices and applications will process data in real time or close to real time as per the configuration. Fog computing environment must be designed to store data in a temporary fashion whereas the same data can be saved to the cloud for the long-term storage and analysis. Cloud platform can send new configuration rules to the Fog IoT devices and Fog applications per business requirements. Cloud platform will act as the Primary / Backup Controller for the IoT devices and its applications.

D. Benefits of Fog Computing

Fog computing brings much needed flexibility for the consumers and vendors. Vendors can deploy applications per customer requirements. Consumers can deploy the same security models to the Fog computing devices thus reducing IT management costs Using Fog Computing we can allocate the necessary bandwidth thus allowing other apps to run smoothly Organizations that embrace fog computing will gain deeper and faster insight giving them better business agility, better

service levels and better IT security. Fog computing may help bridge the gap that has been found when it comes to bringing 5G into the SOHO. The problem is that the 28Ghz signal that 5G rides on is blocked by the coating that is on most of our exterior windows. The mm wave is left on the window sill. Benefits of Fog Computing Fog computing brings much needed flexibility for the consumers and vendors. Vendors can deploy applications per customer requirements Consumers can deploy the same security models to the Fog computing devices thus reducing unwanted expenses A few advantages include: Low Latency, Improved Security posture, scalability,Reduced Operational Costs. Let's discuss few of these in detail. Low Latency provides quick access to data thus saving valuable time and resources. The data generated is examined, analyzed and processed locally. Existing security control policies can be implemented toward the fog computing devices Reduced Operational costs are achieved by processing data locally Few disadvantages include: Authentication, Energy use, infrastructure overhead Since IoT devices are distributed in nature, keeping track of these devices and verifying these units can be challenging Fog computing devices are always on. This will generate more energy to be consumed even when the device is not generating any data Since Fog computing devices generate vast amount of data, storing data can drive up costs Architecture of Fog Computing Transport Layer: This layer transports the data to a permanent location for data analysis Security Layer: This layer provides application level security to make sure that data is not compromised Temporary Storage Layer: This layer distributes and replicates data among several storage environments Processing Layer: This layer identifies and prioritize data and filters out data accordingly [12].

V. Architecture Design

After painstakingly learning about the research, development, theory, technology, architecture, infrastructure, deployment, network creation, adaptation and implementation of 5G, we were faced with the unforeseen dilemma of changing the direction of our project from the Demarcation of 5G to a medical device that would greatly enhance the life of the user as well as the entire circle of individuals involved with the care of the individual. Thus making it a life alerting device when being used in conjunction with 5G. This change occurred because we found that there is no true point of demarcation for 5G into a SOHO configuration due to the existing of film on the windows of office building which is intended to block UV rays but has the unintended consequence of blocking 5G bandwidth. This discovery changed the scope as well as the direction of our project. The new emphasis of our project had yet another unintended outcome, the inability to produce a physical devices that would meet our expectation. We found a device that we could improve upon, but we lacked the ability to acquisition the device do to lack of capital. We would need additional time to acquire permission from the copyright holder as well as time to acquire grant funding. Additionally, time would be needed to develop the sensors, and code required to make the device functional. Software would need to be created to make the device compatible with Windows, Android and iOS devices. We would then need to create the prototype and create a test field with controls as well as time to perform the follow-on test and evaluation of the device in order to determine if the device is functional. As referenced in Figure 8, we wanted to exemplify University Of Michigan's prototype device they utilized as a cancer detector [13].

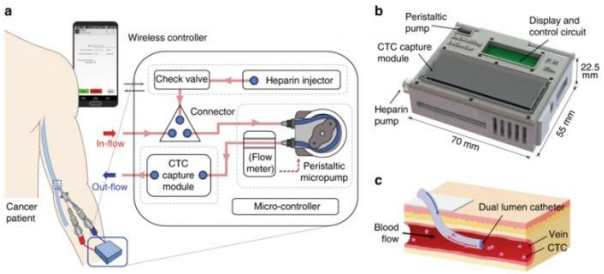

Fig. 8. Portable Cancer Detector

VI. Project Requirements

We would like to take the properties of 5G and incorporate it into the medical field. We plan to design a medical device that is 5G capable and can revolutionize the transmission of data. Our group will need to define and highlight what 5G can do for the medical field. 5G wireless integrated with the legacy cellular systems defined above, is at its strongest point right now, possibly revolutionizing we communicate. We wish to investigate the possibilities of a wearable device that can follow a patient throughout his or her day, while moving from a WiFi based system out into the 5G cellular realm. All the while transmitting extreme amounts of data [4].

VII. Pros and Cons

5G has a tremendous upside. As discussed throughout our paper, 5G can open the door for concepts like autonomous vehicles by providing the bandwidth and speeds that these devices need to become fully functional. 5G is also capable of making virtual reality applications operate in real time. Many have voiced concerned about the possible impact of 5G on health. The level of radiation emitted from 5G antennas has been questioned. The FCC declared 5G as safe as of August of 2019. Additionally, the ICNIRP, the International Commission on Non-Ionizing Radiation Protection, has also updated their guidelines for the new standards. 5G is considered non-ionizing radiation which is considered not harmful because it does not break chemical bonds and it does not affect DNA. In fact, Thomas Gere of Huawei communications, stated that 5G has less radiation than a microwave oven and emits 90 less energy than a 4G antenna.

VIII. Conclusion

The possibilities of integrating 5G technology into every day life are endless, but for now, they are just possibilities.

The robust infrastructure required for the technology to thrive is just in its infancy. Coupled with the drawbacks of the inability to penetrate office glass as well as the need for a massive ramp-up of the installation of various types of small cell antennas as well as the lack of the necessary number of small cell networks needed to bring this dream to reality, these concepts are pretty much still just a dream. Some hospitals have already transitioned their infrastructure to a 5G backbone greatly enhancing the amount of data they are capable of transmitting and receiving as well as the services that they are able to provide to their staff members, off site fellows as well as their off campus facilities that exist in remote locations. The increased bandwidth allows for greater command and control of distant robotic surgery, enhanced resolution for magnetic, photographic as well as digital imaging capabilities. Many major cities have also installed 5G increasing the broadband capabilities of wireless devices up to the Gigabyte range. Massive amounts of funding will be required to build the infrastructure needed to make the dream of autonomous vehicles, wearable medical devices, state of the art fire equipment, zero latency IoT devices, Gigabyte data speeds on hand held devices and instantaneous medical care to rural areas as well as 3rd world countries a reality. The looming COVAD-19 pandemic is another major issue to consider as well. It has almost totally crippled the entire global economy by causing governments worldwide to shift resource from infrastructure enhancement to essential services, hospital, supplies and personnel. Additionally corporate bailouts, taxpayer bailout, and unemployment benefits may also greatly impact the funds diverted from funding allocated to build out the 5G infrastructure to areas to have an immediate need.

A. Acronyms

3GPP 3rd Generation Partnership Project

IoT Internet of Things

SOHO Small Office Home Office

ISDN Integrated Service Digital Network

ADSL Asynchronous Digital Subscriber Lines

LTE Long Term Evolution

HVAC Heating, Ventilation and air conditioning

ARIB The Association of Radio Industries and Businesses, Japan

WBSN Wireless Body Sensor Network

ATIS The Alliance for Telecommunications Industry Solutions, USA

CCSA China Communications Standards Association

ETSI The European Telecommunications Standards Institute

TSDSI Telecommunications Standards Development Society, India

TTA Telecommunications Technology Association, Korea

TTC Telecommunication Technology Committee, Japan

BPON Broadband Passive Optical Network

GPON Gigabyte Passive Optical Network

Demarc also known as the MPOP

MPOP minimum point of penetration

DAS Distributed Antenna System

C-RAN Centralized Radio Access Network

SO Small Office

AR Augmented Reality

OBA Oxygen Breathing Apparatus

NR New Radio (5G)

CDMA Code-division multiple access

WCDMA Wideband Code Division Multiple Access

ICNIRP the International Commission on Non-Ionizing Radiation Protection

FCC Federal Communication Commission

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