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Domain: Mobile Computing

Subdomain: Advancement in Mobile Computing

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CHAPTER 1

ADVANCEMENT IN MOBILE TECHNOLOGIES

1.1 5GAA

The 5G Automotive Association (5GAA) is a global cross-industry organisation of companies from the automotive, technology and telecommunications industries (ICT), working together to develop end-to-end solutions for future mobility and transportation services. Created in 2016, the Association is comprised of over 50 members which mission is to develop, test and promote communications solutions, initiate their standardization and accelerate their commercial availability and global market penetration to address societal need.

The 5G Automotive Association (5GAA) encourages the automotive, technology, and telecommunications industries and the European Commission to be ambitious when evaluating technologies for connected, autonomous vehicles. 5GAA is confident that cellular communication technology (C-V2X) has the most benefits when applied to connected, self-driving cars. It has provided its views to the Commission in a workshop and a letter with recommendations. Since its launch one year ago, over 50 industry leaders from the automotive, technology and telecommunications industries have teamed up in 5GAA to accelerate C-V2X technology development and its evolution to 5G-V2X for enhanced safety, automated driving and connected mobility

Christoph Voigt, Chairman of 5GAA said, 5GAA is confident that cellular technology (including direct vehicle-to-vehicle communication at 5.9 GHz) has the potential to lead to the best outcomes in the long run. We are strongly relying on the European institutional support to put in place a regulatory framework allowing for an industry-driven and swift deployment of this technology. It is crucial to consider how the 5.9 GHz band, the life blood of wireless vehicle communication, can be used efficiently in the context of 5G technology evolution, road safety, and economic scalability. The automotive and transportation sectors, both public and private, are making significant investment commitments. Therefore, we are urging the European Commission to allow the ITS-G5 and C-V2X stakeholders to work together towards an agreement on the future of connected and automated cars, without a premature and cumbersome legislative decision. 5GAA has recently provided its views to the Commission in a workshop and a letter with recommendations.

1.1.1 Helping vehicles understand the environment they are navigating

Launched in September 2016 by 8 founding members the 5GAA has in less than a year grown to include over 50 leaders from the automotive, technology and telecom industries who collaborate cross-industry on the future of transport. 5GAAs mission is to develop, test, and promote communications solutions, initiate their standardization and accelerate their commercial availability and global market penetration. The objective is to address societys connected mobility and road safety needs with applications such as autonomous driving, ubiquitous access to services and integration into smart city and intelligent transportation.

Connected vehicles use communication technology to not only communicate with other vehicles but also with road infrastructure, other road users such as pedestrians, and the Internet e.g. to provide traffic updates and parking guidance. Use cases include collision warnings, traffic jam ahead warnings, green light optimal speed advisory, parking guidance, and assisting drivers in tackling treacherous traffic situations (e.g. turning left at a crossroads). Connected vehicles will eventually reduce pollution, and make traffic more efficient, reducing congestion in cities and improving the flow of goods and people.

1.2 WHAT IS MILLIMETER WAVE?

Millimeter waves, also known as extremely high frequency (EHF), is a band of radio frequencies that is well suited for 5G networks. Compared to the frequencies below 5 GHz previously used by mobile devices, millimeter wave technology allows transmission on frequencies between 30 GHz and 300 GHz. These frequencies are called millimeter waves because they have wavelengths between 1 mm and 10 mm, while the wavelengths of the radio waves currently used by smartphones are mostly several dozen centimeters.

So far, only radar systems and satellites use millimeter waves. However, now some mobile network providers have also started using millimeter waves (for example, to transmit data between two fixed points, such as base stations). Nonetheless, the use of millimeter wave frequencies to connect mobile users to nearby base stations is an

entirely new approach.

1.2.1 What Are the Advantages of Millimeter Wave Technology?

There are two ways to increase the speed of wireless data transmission: increase the spectrum utilization, or increase the spectrum bandwidth. Compared to the first approach, increasing the spectrum bandwidth is simpler and more direct. Without changing the spectrum utilization, increasing the available bandwidth several times over can increase data transmission speeds by a similar amount. The problem is that the commonly used frequencies below 5 GHz are already extremely crowded, so where can we find new spectrum resources? 5G's use of millimeter waves uses the second of the two methods to increase transmission speeds.

Based on communication principles, the maximum signal bandwidth in wireless communication is about 5% of the carrier frequency. Therefore, the higher the carrier frequency, the greater the signal bandwidth. Thats why, among the millimeter-wave frequencies, 28 GHz and 60 GHz are the most promising frequencies for 5G. The 28 GHz band can provide an available spectrum bandwidth of up to 1 GHz, while each channel in the 60 GHz band can provide an available signal bandwidth of 2 GHz (a total available spectrum of 9 GHz divided between four channels).

Comparatively, the maximum carrier frequency of the 4G-LTE band, 2 GHz, provides an available spectrum bandwidth of only 100 MHz. Therefore, using millimeter wave frequencies can easily increase the spectrum bandwidth by a factor of 10, allowing for a massive increase in transmission speeds.

1.2.2 What Are the Disadvantages of Millimeter Wave Technology?

The use of millimeter waves has one major drawback. Millimeter waves are not capable of penetrating structures and other obstacles. Even leaves or rain can absorb these signals. This is also why 5G networks will have to adopt the small base station method to enhance traditional cell tower infrastructure.

Because millimeter waves have high frequencies and short wavelengths, the antennas used to receive them can be smaller, allowing for the construction of small base stations. We can predict that, in the future, 5G mobile communication will no longer

depend on the construction of large-scale base stations, but rather many small base stations. This will allow 5G to cover peripheral areas not reached by large base stations.

Silicon Talks author Li Yirei said that the present 5G band plans adopted by major carriers use more traditional frequencies below 6 GHz to ensure signal coverage in open spaces, and use micro base stations with millimeter wave technology to provide ultra-fast data transmission indoors.

Using millimeter waves and other 5G technology, engineers hope that 5G networks will not only serve smartphone users, but also play a critical role in self-driving cars, VR, IoT, and other fields.

Researchers and companies already have high hopes for 5G, promising consumers that it will provide ultra-low latency and unprecedented data speeds. If they can overcome the remaining challenges and find a clear way to allow cooperation throughout the entire ecosystem, we can expect to see the commercial deployment of 5G services within the next five years.

1.3 URLLC

As per 3GPP Release 15 5G-NR, Ultra-Reliable Low-Latency Communication (URLLC) is a set of features that provide low latency and ultra-high reliability for mission critical applications such as industrial internet, smart grids, remote surgery and intelligent transportation systems.

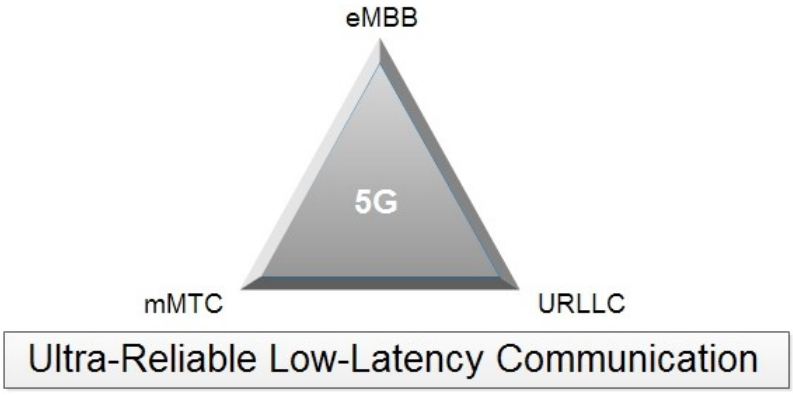

Figure 1.1: Ultra-Reliable Low-Latency Communication

5G offers three services that could transform current industries and create new industries. They are:

- Enhanced mobile broadband (eMBB): Faster speeds for use cases requiring high data rates like large-scale video streaming, and virtual reality.
- Ultra-reliable low latency communications (URLLC): Low latency for mission-critical services.
- Massive Machine Type Communication (mMTC): Providing internet access for sensing, metering, and monitoring devices.

3GPP has specified URLLC as a key feature for Release 15 5G NR, in addition to eMBB. As per 3GPP Release 14, Latency with 4G LTE is in the 4-millisecond range but with the introduction of URLLC in Release 15, the target is 1-millisecond. URLLC also provides end-to-end security and 99.999 percent reliability.
The design of a low-latency and high-reliability service involves several components: Integrated frame structure, incredibly fast turnaround, efficient control and data resource sharing, grant-free based uplink transmission, and advanced channel coding schemes. But the designing of physical layer will be the most challenging thing as satisfying low latency and ultra-high reliability - two conflicting requirements at the same time is not an easy task.

1.3.1 What is URLLC?

Ultra-reliable low-latency communication, or URLLC, is one of several different types of use cases supported by the 5G New Radio (NR) standard, as stipulated by 3GPP (3rd Generation Partnership Project) Release 15. URLLC will cater to multiple advanced services for latency0-sensitive connected devices, such as factory automation, autonomous driving, the industrial internet and smart grid or robotic surgeries.
But, in order to understand URLLC, you must understand 5G NR. This is the global standard for a much stronger and more capable cellular network. With it we will deliver faster, more reliable mobile services, and a much smoother user experience from everyday cellphone users to the internet of things (IoT) to smart technologies on a massive scale.
Other services that 5G will support include eMBB (Enhanced Mobile Broadband)

that will supply high bandwidth internet access for wireless connectivity, large-scale video streaming, and virtual reality. And mMTC (Massive Machine Type Communication) which supports internet access for sensing, metering, and monitoring devices. But well focus on URLLC for now. One of the key features of URLLC is the LL, or low latency. Low latency is important for gadgets that, say, drive themselves, or perform prostate surgeries. Low latency allows a network to be optimized for processing incredibly large amounts of data with minimal delay (or, latency). The networks need to adapt to a broad amount of changing data in real time. 5G will enable this service to function. URLLC is, arguably, the most promising addition to upcoming 5G capabilities, but it will also be the hardest to secure; URLLC requires a quality of service (QoS) totally different from mobile broadband services. It will provide networks with instantaneous and intelligent systems, though it will require transitioning out of the core network.

This new URLLC wireless connectivity will guarantee latency to be 1ms or less. In order for this interface to achieve low latency, all the devices have to synchronize to the same time-base. Time-sensitive networking is another component of the 5G URLLC capabilities. This will allow the shapers used for managing traffic to be time aware.

The design of a low-latency and high-reliability service involves several components: Integrated frame structure, incredibly fast turnaround, efficient control and data resource sharing, grant-free based uplink transmission, and advanced channel coding schemes. Uplink grant-free structures guarantee a reduction in user equipment (UE) latency transmission through avoiding the middle-man process of acquiring a dedicated scheduling grant.

Ultra-reliable low-latency communication represents a complete game-changer for communications technology in the modern age. With it, we can conduct remote surgeries, have our cars drive for us, and increase machine productivity by large-scale factors. But URLLC simply isnt possible without the development and implementation of 5G NR; the non-standalone version of 5G NR is slated to be released later this year. The standalone version should be released sometime in 2020.

1.3.2 LTE-A or LTE Advanced

LTE-A or LTE Advanced is the upgraded version of LTE, which increases the stability, bandwidth, and speed of traditional LTE networks. According to 3GPP - "The main new functionalities introduced in LTE-Advanced are Carrier Aggregation (CA), enhanced use of multi-antenna techniques (MIMO) and support for Relay Nodes (RN)".

Carrier Aggregation (CA) is a feature of LTE-Advanced that allows mobile operators to combine two or more LTE carriers into single data channel to increase the capacity of the network and the data rates by exploiting fragmented spectrum allocations.

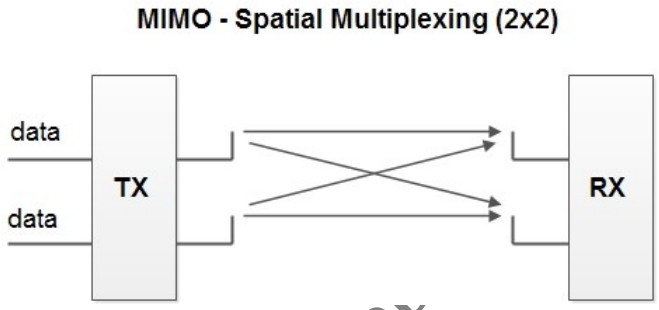

Figure 1.2: MIMO - Multiplexing

Multi-input Multi-output (MIMO) technology is the use of multiple receive and transmit antennas to establish a communications link between two, or more, communications systems with greater throughput than would be possible with a single antenna system.

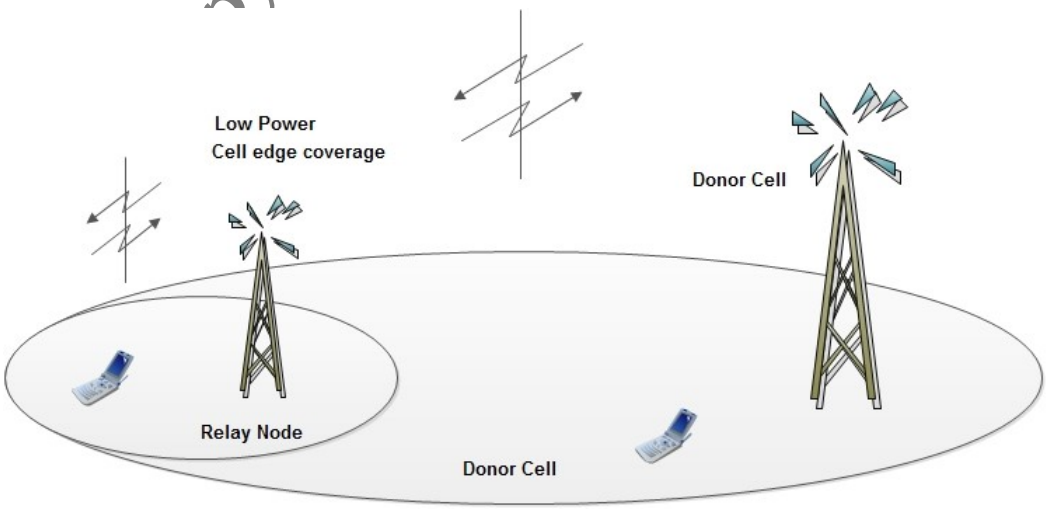

Figure 1.3: Multi-input Multi-output (MIMO) technology

Relay Nodes are low powered base stations that increases the coverage and capacity at cell edges. They also provide coverage in the areas where there is no fiber connection

1.3.3 LTE-Advanced features

- Increased peak data rate: Downlink 3 Gbps, Uplink 1.5 Gbps
- Higher spectral efficiency: Uplink 16bps/Hz, Downlink 30 bps/Hz
- Increased number of simultaneously active subscribers
- Improved performance at cell edges, e.g. for Downlink 2x2 MIMO by at least 2.40 bps/Hz/cell

Table 1.1: Comparison of LTE-A with other technologies

Parameter	WCDMA (UMTS)	HSPA+	LTE	LTE-
Downlink speed	384 Kbps	1-28 Mbps	10 100 Mbps	1 Gbp
Uplink speed	128 Kbps	11 Mbps	5 50 Mbps	500 M
Latency	150 ms	50ms (max)	10 ms	less than
3GPP Releases	Rel 99/4	Rel 7	Rel 8	Rel 1
Access Methodology	CDMA	CDMA	OFDMA / SC-FDMA	OFDMA / S

1.3.4 How does LTE-A work?

As the name implies, LTE-Advanced is simply an evolved version of current LTE connectivity, using a variety of additional techniques to warrant the advanced name. The new functionalities introduced in LTE-Advanced are Carrier Aggregation (CA), better use of existing multi-antenna techniques (MIMO), and support for Relay Nodes. All of these are designed to increase the stability, bandwidth, and speed of LTE networks and connections. Weve also seen the arrival of LTE-Advanced Pro also known as Gigabit LTE in some markets (3GPP Release 13 and up). So how does this differ from standard LTE-A? This Sierra Wireless infographic does a good job of illustrating how it fits together.

LTE-A Pro/Gigabit LTE uses existing 256QAM technology, more advanced carrier aggregation, and the other techniques to boost speeds over vanilla LTE-A. Its also

set to be a major part of 5G deployments, essentially blanketing areas in coverage where 5G isnt available.

1.4 LTE BASED MULTIFIRE

MulteFire is a technology for deploying LTE in unlicensed spectrum that was developed by Qualcomm. Unlike the strategies of LTE-U or License-Assisted Access, which rely on a licensed spectrum anchor aggregated with LTE in an unlicensed band, MulteFire allows the standalone use of LTE in unlicensed spectrum. MulteFire can be used to deploy mobile broadband data services and support Voice over LTE. It can support handovers among cells in a small-cell deployment and is capable of interworking with external mobile networks for service continuity, according to a technical paper on the technology.

Our growing reliance on wireless connectivity to deliver rich content to our ever-growing number of devices continues to put a severe strain on the resource that delivers itnetwork capacity. And the trend is astounding. In fact, the industry is preparing for an 1000x increase in mobile data traffic. At Qualcomm, we invent technology and solutions to cost-effectively meet this network capacity challenge. And now we are developing a new technology at Qualcomm Technologies, Inc. called MulteFire, envisioned to play a critical role in addressing this 1000x mobile data challenge. But before I introduce MulteFire, first some background.

Solving the 1000x challenge will require multiple strategies. One key strategy is to make the best use of unlicensed spectrum. Of course licensed spectrum continues to be the most pivotal piece of the puzzle. And taking advantage of Qualcomm technologies, network operators are working to densify their networksdeploying more small cells in licensed spectrum, which ensures a predictable performance (thanks to its exclusive use). But to reach 1000x, we must opportunistically use capacity in unlicensed spectrumsuch as 5 GHzas well. One challenge with unlicensed spectrum is that it is shared amongst multiple technologies and users, which impacts on the ability to ensure a seamless, high-quality experience at all times. This becomes especially challenging in large venues such as enterprises, stadiums, and campuses where large numbers of people (with a ravenous appetite for mobile content) come together.

LTE was designed for high-performance mobile broadband and hyper-dense deployments. So we asked, what if we took the benefits of LTE (and its vast ecosystem), and extended them to unlicensed spectrum?

The industry response was LTE in unlicensed spectrumin the form of LTE-U (based on 3GPP Rel. 10/11/12 and defined by the LTE-U forum) and LAA (Licensed-Assisted Access as defined by 3GPP release 13). Thanks to a robust radio link, synchronized nodes with better coordination, and carrier aggregation with an anchor in licensed spectrum, LTE-U/LAA delivers better network performance and an enhanced user experience compared to carrier Wi-Fi, providing mobile operators a solution for making better use of unlicensed spectrum. But could we extend the benefits of the LTE technology and ecosystem even further?

The answer to this question is MulteFirea new, LTE-based technology that solely operates in unlicensed spectrum, and doesnt require an anchor in licensed spectrum. The new technology broadens the LTE ecosystem to entities that may not own licensed spectrum, such as Internet Service Providers and enterprise/venue owners. MulteFire also benefits mobile network operators (primary licensed spectrum holders), providing them with new deployment opportunities for offloading and augmenting their mobile networks. The ultimate goal of MulteFire is to ensure the best possible user experience for wireless access to the Internet or when making video/voice calls, especially in hyper-dense environments as described earlier.

MulteFire will accomplish this by combining the performance benefits of LTE technology (enhanced capacity, range, mobility, and quality-of-experience) with the simplicity of Wi-Fi-like deployments. MulteFire will use the signals and channelization of the robust LTE radio link, while also leveraging evolving LTE technologies for self-organizing small cells suited for hyper-dense deployments. MulteFire will deliver these LTE-like performance benefits to more deployment scenarios with Wi-Fi-like simplicitya leaner, self-contained network architecture that is suitable for neutral deployments where any deployment can service any device.

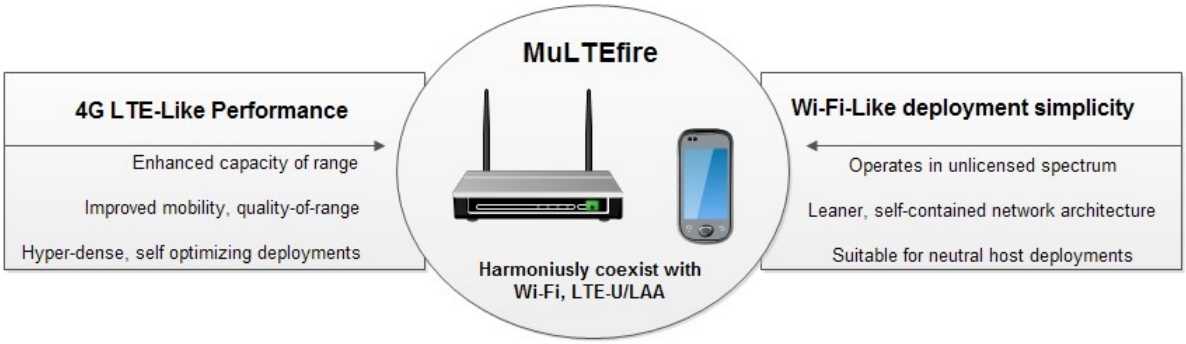

Figure 1.4: Multifire

1.4.1 Way of working Multifire

Fair sharing with other technologies in unlicensed spectrum, such as Wi-Fi, is at the core of MulteFires requirements. Qualcomm Research, a division of Qualcomm Technologies, Inc., has extensively studied and tested the coexistence on our over-the-air system to ensure LTE-U/LAA will be a good neighbor to Wi-Fi. These coexistence features ensure that Wi-Fi performance is not adversely impacted. To the contrary, in many cases, Wi-Fi performance will actually be improved by LTE-U/LAA. MulteFire will implement similar coexistence features and we envision similar results.

MulteFire will create expanded opportunities for small cell deployments, especially in hyper-dense environments and indoor locations. Who will benefit? It can be deployed by small businesses, enterprises, venue owners, Internet service provider/cable companies, and mobile operators in various deployment models including single access node, coverage islands, or bigger clusters for mobility (within the clusters).

MulteFire is suitable for neutral host services where any deployment can serve any device out-of-box, using neutral unlicensed spectrum like 5 GHz. And it can be deployed by service providers or directly by users. This will enable entities, such as Internet Service Providers and enterprise/venue owners, to leverage their deployment assets (fixed broadband, physical location, and customer relationships) and provide nomadic wireless access services to any end user (no subscription or SIM required). Additionally, MulteFire can interface with mobile networks to offer enhanced data offload services to mobile operators (SIM required).

At Qualcomm Research, a division of Qualcomm Technologies, Inc., we are actively developing MulteFire technology, taking advantage of our decades of experience in

3G/4G and Wi-Fi. Our focus in the months ahead is to initiate work with the ecosystem to develop industry-wide specifications for this technology. The actual release of equipment for deployment of a MulteFire system will depend on market demand and customer requests. Meanwhile, Qualcomm remains committed to the best use of licensed and unlicensed spectrum, evolving LTE/LTE Advanced (including LTE-U/LAA) and Wi-Fi (including 802.11ax) to their fullest potential in parallel.

1.5 VIRTUAL REALITY

Virtual reality technology plays an important role in realizing Telesensation. Through it, a virtual world is created that viewers can enter and walk through and where they can handle virtual objects. The virtual world allows us a stereoscopic view from front or side, depending on our viewpoint, just as in the real world. The ability to enter and walk through the virtual world and handle virtual objects using hand gestures makes VR interactive, and this is one of its most important features.

Communication can be humanhuman communication, humanenvironment communication, or humancomputer communication. In the case of humanhuman communication, a variety of means are at our disposal. We talk together to communicate. We write letters or draw pictures and sometimes communicate using images and motion pictures. In humanenvironment communication, we recognize our environment via our five senses: feeling, touch, taste, vision, and smell. In humancomputer communication, we interact with a computer by means of a mouse, a touch pad, or a keyboard.

Humanhuman communication and humanenvironment communication have been developed over a long history of interaction. It is desirable to provide human beings with a human-friendly environment where we can interact with computers just as easily as we interact in humanhuman communication or humanenvironment communication.

The goal of VR is to provide human beings with a virtual environment where we can interact with a computer just as we do in the real world, that is, by talking with a virtual human in a spoken language, by writing a letter, or by drawing a picture. We can grasp a virtual object by hand gesture and bring it to another place. In a

human-friendly virtual environment, we can interact with a computer without any difficulties or barriers. When a virtual landscape is generated by VR technology, we can go there just as if it were a real landscape. Providing not only a 3D image of the landscape but also sound and smell helps us enjoy the scenery.

In Oita prefecture, Japan, there is a museum where visitors can experience a virtual world. Upon entering the museum, we see a large screen in front of the seats. By sitting on a seat and wearing special glasses, visitors can enter a large virtual flower and smell it.

At ATR Communication Systems Laboratories, Kyoto, Japan, a virtual space teleconferencing system was developed in 1992. This next-generation video conference system provides participants a human-friendly environment for meeting and collaborating. They can view objects stereoscopically and have front or side views of the objects depending on their viewpoint. They can handle an object by means of hand gestures. In this system, each participant is at a different location, and all sites are connected via the network. Each site has a virtual conference room with a large screen in front of seats. On the screen, 3D images of real human beings are displayed stereoscopically, and participants can have stereoscopic views of various objects displayed on screen. They can have eye contact with each other. They can conduct a meeting as if they were gathered in the same place.

The images motion is controlled by the real humans motion. The participant wears shutter glasses and has sensors on face, hands, and body to detect motion. The shutter glasses provide a stereoscopic view. On the basis of the movement information, the images of the virtual person or object is deformed and displayed on the screen to match the viewers perspective.

In the conventional video conference system, participants can meet face to face. However, it is very difficult to make eye contact and to have different views of objects according to the viewers perspective. In the real world, a viewer can take a side view of an object just by moving to the side of the object. In the virtual space teleconferencing system, participants can make eye contact and take different views of the object to match their perspective. In the conventional video conference system, a participant cannot go inside the scene displayed on the screen, whereas in

the virtual system he or she can enter the virtual space, walk through it, and grasp a virtual object by means of hand gesture, even feeling the heft of the object. To summarize, a viewer in the virtual world, can have a stereoscopic view of an object. This is called stereoscopic display. The viewer can enter the virtual world and walk through it. This is called walk-through. The viewer can take different views of the object according to his or her viewpoint. This is called interaction. The viewer can touch and grasp a virtual object and feel its heft. This is called force feedback. In the virtual world, even a collision can be detected.

To accomplish these functions, the viewer wears shutter glasses or a head-mounted display; this gives a stereoscopic view of the object, because the right image of the object enters the right eye and the left image enters the left eye. When the technologies of the lenticular screen and holography have been developed enough, viewers should be able to have a stereoscopic view with the naked eye. This involves detecting the viewers viewpoint via a sensor attached near the viewers eye and, based on this information, adjusting, the objects display on the screen. Object handling with hand gesture is accomplished by means of a data glove with sensor, that detects hand shape and hand motion. Again, this information is used to adjust display of the object. The technology for detecting hand motion and hand shape without use of a data glove is currently under study.

1.6 AUGMENTED REALITY

Augmented Reality (AR) refers to deploying virtual image over real-world objects. The overlay is executed simultaneously with the input received from a camera or another input device like smart glasses. This superimposition of virtual images over real-world objects creates an illusion that can effectively engage users in a virtual world.

With the growing traction towards Augmented Reality technology business leaders are exploring innovative ways to harness its potential. There are many successful AR apps and use cases in business and new innovations are happening rapidly in this space. But to leverage any modern technology it is crucial to understand its fundamentals and working. Since AR is an evolving technology, exploring the online

knowledge base can help you fully understand its potential and uses. This will help you think of creative ways to leverage it, avoid mistakes and gain a competitive edge in the market. In this blog, we will understand how AR works and the fundamentals of the augmented reality technology.

1.6.1 How does AR Work

3 Augmented Reality Technologies Used Today: The Augmented Reality technology can work using one of the following three approaches:

1.6.1.1 1. SLAM:

SLAM (Simultaneous Localization and Mapping) is the most effective way to render virtual images over real-world objects. SLAM simultaneously localizes sensors with respect to their surroundings, while at the same time mapping the structure of the environment. SLAM is an approach to solve complex AR simulation problems and is not any specific algorithm or software. The SLAM system is, in fact, a set of algorithms aimed at solving simultaneous localization and mapping problem. This can be done in multiple ways and now every augmented reality development kit has its upon to providing SLAM functionality.

1.6.1.2 2. Recognition based:

Recognition (or marker) based augmented reality uses a camera to identify visual markers or objects, such as a QR/2D code or natural feature tracking (NFT) markers, to showcase an overlay only when the marker is sensed by the device. Marker-based AR technology depends upon device camera to distinguish a marker from other real-world objects. Not only the marker image but the position and orientation can also be calculated. Once recognized the marker on screen is replaced with a virtual 3D version of the corresponding object. This is done to permit the user to observe the object in more detail and from various angles. Rotating the marker would rotate the virtual replication as well.

1.6.1.3 3. Location Based:

Contrary to recognition based, location-based AR relies on a GPS, digital compass, velocity meter, or accelerometer to provide data about the location and the augmented reality visualizations are activated based on these inputs. It is also known as markerless augmented reality. The location detection features in smartphones make it easy to leverage this type of augmented reality technology, making it quite popular. Some common uses of location-based AR include mapping directions, finding nearby services, and other location-centric mobile apps. How does augmented reality work on mobile? There are basically 2 types of AR which can be used in mobile apps. Each of them differs in terms of used sensors and technologies, but the basic principle is still the same: they display virtual 3D objects on top of a camera view.

1.6.2 Marker-based Augmented Reality

Marker-based AR is, in my opinion, the most powerful technology. It uses image-recognition algorithms to specify the position and rotation of markers. After that it displays, for example, a 3D object in the specified place. You may ask: what can be the marker? Well, at the beginning image recognition wasnt well developed and the marker was just a QR code. But currently there are tools that can recognize almost everything - from text to human face. Lets see some cool examples of marker-based AR solutions.

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