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COMMUNICATION SYSTEMS: AN OVERVIEW OF PAST, PRESENT AND FUTURISTIC OUTLOOK

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Abstract. In contemporary times, communication systems have become the major drivers of globalization and trade facilitation. From its simple beginning to the more recent 5G and 6G technologies which are at various stages of development and applications, capable of entrenching the era of the Internet of Things (IoT), advancing Machine-to Machine (M-2-M) integration, and further revolutionizing the speed of seamless communication between smart devices. Significant advancements have also been achieved in the area of auxiliary technology interfaces incorporated into mobile communication systems such as the wireless LAN (Wi-Fi), Bluetooth, Infra-Red (IR), and sundry communication systems operating at the higher frequency bands of the electromagnetic spectrum. Against this backdrop, this work reviewed some communication systems highlighting their technology and developmental trends. Furthermore, it attempts to accurately forecast the probable direction of future advancements in communication systems, based on a painstaking trend and pattern analysis of the technological improvements of Bluetooth, Radar, and Wi-Fi technologies and some other communication systems in the past decade.

Keywords: Communication Systems; Bluetooth; Radar; WI-FI; Transmitter, Receiver.

1. INTRODUCTION

In its most basic form, communication is the conveyance of information—an act inherently intertwined with the essence of sharing. It encompasses the transmission of information from one location to another. Our daily lives bear witness to the widespread use of diverse communication systems, including but not limited to telephone, radio, television, and the Internet (world-wide-web). These sophisticated mediums enable instantaneous communication across continents, facilitating business transactions, and the swift exchange of valuable information pertaining to global events and occurrences [1]. Fundamentally, contemporary society demonstrates a preference for the integration of wired and mobile networks alongside a diverse array of internet-enabled smart devices to facilitate meaningful human interactions. This trend is notably evident in the incorporation of instant messaging and video-conferencing interfaces across various platforms, including emails, Facebook, Signal, Skype, Telegram, Twitter, Viber, WhatsApp, and others. The aim is to enhance the seamless and cost-effective exchange of information, all while alleviating the burdens associated with paper wastage [2].

Communication systems play a pivotal role by serving as the framework that consolidates the vast pool of information available on the world-wide-web. This consolidated information is made accessible to internet users with a simple click, transcending geographical distances and fostering a sense of global interconnectedness—akin to a virtual global village. Not only do these systems facilitate information exchange, but they also contribute to the interconnectivity of remote users in an increasingly interconnected world [2]. The significance of electronic communication is particularly pronounced in corporate environments, where it confers numerous advantages. These include swiftness, extensive coverage, cost-effectiveness, and the facilitation of feedback exchange. Moreover, electronic communication provides a robust platform for effectively managing global-scale operations, thereby enhancing organizational efficiency [2].

Added to this is the miniaturization of most communication gadgets, such that a sizable portion of today's society is becoming increasingly dependent on smartphones in what has been described as the communication revolution [3]. More so, several new modes of electrical communication and communication systems are emerging from time to time as a result of continuous advancement in technology and the desire for faster communication links. This has led to a scramble for communication systems operating in the higher frequency bands of the electromagnetic spectrum above 10GHz, identified to be more susceptible to absorption, scattering, and other forms of unwanted attenuation and fading, due to interaction with atmospheric elements along the signal propagation path and sundry signal degrading factors [1].

Accordingly, the aforementioned challenges are being addressed and analyzed in this paper by a shift to communication systems operating in the Ka and higher bands, to address the dearth in bandwidth at the lower electromagnetic spectrum and the utilization of smart antennas with optimal directivity gain in tandem with the significant advancements in the development of the mobile networks and its intended applications. Meanwhile, the basic objective of the communication system remains the transmission of information from the originator, passing through a channel to the intended recipient [3]. This research also provides a holistic examination of communication systems, encompassing their historical evolution, current state, and future prospects. Understanding the past offers insights into technological foundations, while analyzing the present reveals contemporary trends. The exploration of a futuristic outlook is crucial for anticipating emerging technologies and challenges. In our globally interconnected era, this study holds significance for comprehending global dynamics and informing innovation and policy decisions in the realm of communication systems.

2. ELEMENTS OF COMMUNICATION SYSTEM

A typical communication system will have at least five main blocks, including the information source, transmitter, channel, receiver, and destination. However, from a practical communication systems design point of view, only the transmitter, channel, and receiver are important as the designer has little or no control over the two other blocks. In addition, communication in electrical form takes place mainly within these three blocks [3] as highlighted in Fig. 1:

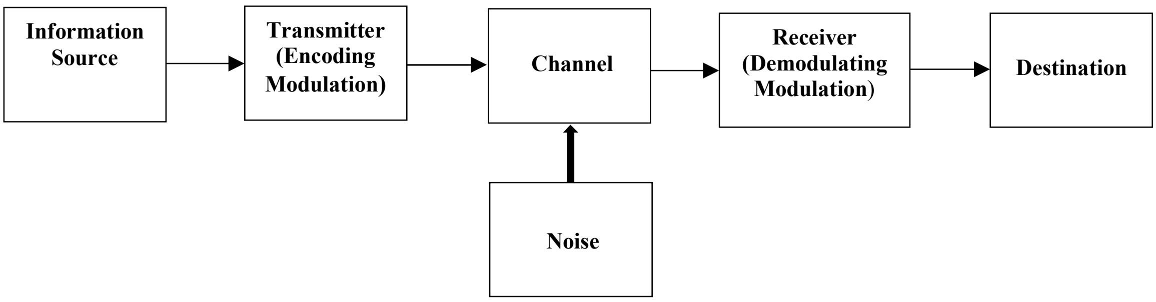

Figure 1 Block schematic diagram of a communication system [3]

2.1. Information source

The information source converts information into a physical quantity known as the message signal. For electrical communication purposes, the message signal is converted into electrical form through a suitable transducer, which converts energy from one form to another. It is the electrical version of the message signal that is inputted into the transmitter block of the communication system.

2.2. Transmitter

The objective of the transmitter as a block is to collect the incoming message signal and modify it into a suitable mode (where necessary) so that it can be effectively transmitted through an appropriate channel to the receiving point [2]. It carries out such operations as amplification, generation of the high-frequency carrier signal, modulation, and the radiation of the modulated signal. The amplification process essentially involves amplifying the signal amplitude values and also adding required power levels. The modulated signal is then transmitted or radiated into the atmosphere using an antenna as the transducer. This converts the message signal energy in guided waveform to free space electromagnetic waves [3] as shown in Fig. 2:

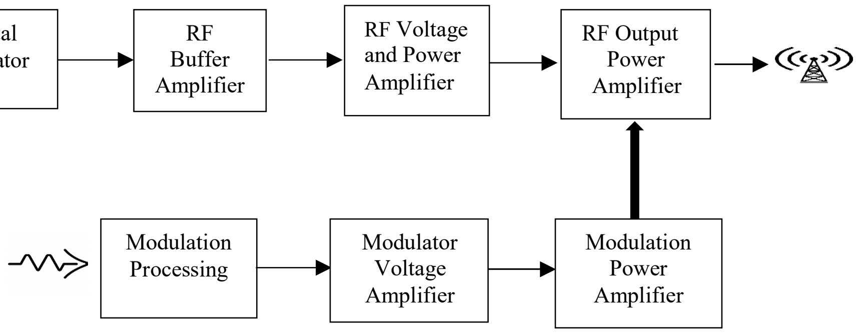

Figure 2 Block schematic diagram of a typical radio transmitter [3]

2.3. Channel

This is the physical medium that connects the transmitter to the receiver in the form of copper wire, coaxial cable, fiber optic cable, waveguide, and the free space or atmosphere. The choice of any particular channel depends on the feasibility and the purpose of the communication system. For instance, if the objective is to provide connectivity for speech communication amongst a group of people working in the same physically localized place, then copper wire may be the best choice. Alternatively, if the information needs to be sent to several people scattered in different physical geographical locations, then the free space becomes the preferred means of signal propagation. The channel plays the role of a transition device that, conveys the transmitted message signal so that maximum information can be delivered to the receiver. It may also mean the frequency range allocated to a particular service or transmission, such as a television channel referring to the allowable carrier bandwidth with modulation [1].

2.4. Receiver

The receiver block receives the incoming modified version of the message signal from the channel and processes it to recreate the original (non-electrical) form of the message signal through demodulation. There are a great variety of receivers in modern-day communication systems, depending on the processing required to recreate the original message signal and also the final presentation of the message to the destination. The purpose of the receiver and form of output display influence its construction as much as the type of modulation system used. Accordingly, the receiver can be a very simple crystal receiver, with headphones, to a far more complex radar receiver, with its array antenna arrangements and visual display system. The output of a receiver may be fed to a loudspeaker, video display unit, teletypewriter, various radar displays, television, pen recorder, or computer in each instance different arrangements must be made, each affecting the receiver design.

Note that the transmitter and receiver must be in agreement with the modulation methods used. A schematic representative diagram of a receiver is given as shown in Fig. 3:

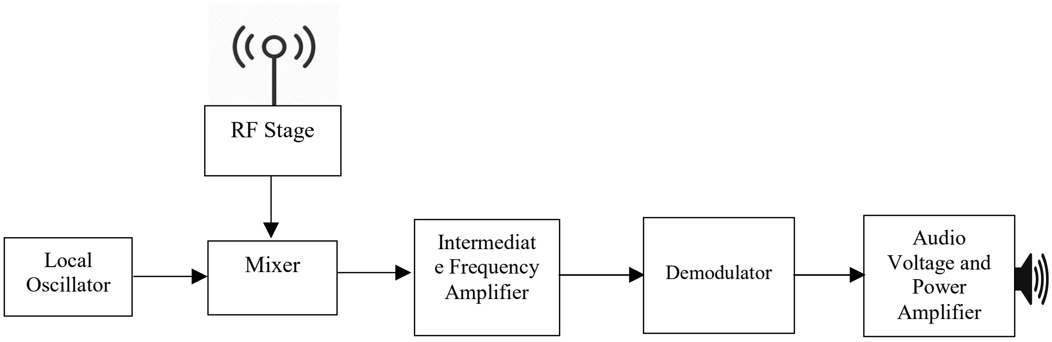

Figure 3 Schematic diagram of an AM Super Heterodyne receiver

2.5. Destination

The destination is the final block in the communication system, which collects the message signal from the receiver and processes it to comprehend the information present in it. Usually, humans will be the destination block. The incoming message signal via speech mode is processed by the speech perception system to comprehend the information. Similarly, the message signal of video and/or written script is processed by the visual perception system. Even though there are several theories put forward about the comprehension of the information from the message signal, the robustness exhibited by the human system in extracting information even under very noisy conditions infers that the entire sequence is less understood as of now, as the human brain is the least understood part of the human body in terms of its functional ability.

2.5. Need for modulation in communication engineering

The term modulation means various methods of super-imposing intelligent signals on a radio frequency carrier. The signal to be regulated is termed the carrier, while that which dictates regulation is called the modulating signal. The modulation process is the most important operation in modern communication systems as it is extensively applied to significantly increase the distance traveled by a signal propagated free space, reduce interference between the baseband and unwanted noise within the frequency range of (20Hz-20KHz) and increase bandwidth since the use of modulation process helps in shifting the baseband signals frequencies to a much higher frequency range where it can occupy only negligible percentage of the carrier spectrum implying that a greater number of message signals can be accommodated at higher frequencies, hence faster signal transmission and reception rates. The modulated signal is retrieved through demodulation, which is conveyed to the intended recipient.

3. COMMUNICATION SYSTEM

There are many modern communication systems with broad electrical communication applications in contemporary society. Highlighted below are some of them.

3.1 Microwave communication system

The Microwave Communication System, otherwise known as relay communication, is a point-to-point system operating in the microwave region of the electromagnetic spectrum corresponding to a wavelength (λ) range of 0.1mm to 1m [4]. It is characterized by low frequency and high wavelength, giving it a higher penetrative power to obstacles and less susceptibility to signal attenuation during propagation through free space associated with higher frequency values. In addition, it can host a large volume of information for a long transmission distance without losing its quality of it. Like most others, a typical microwave communication system also comprises a transmitting/receiving antenna (predominantly called parabolic reflectors), a modulator, and a multiplexing device [5].

Some of the major drawbacks associated with this communication system include complex circuitry, and difficulty to trap when not in the line of sight (LOS) amongst others. However, with the advent of the 5G network, it is expected that a Microwave communication system which can also accommodate 6G and above, will be developed. It is thereby paving way for communication with higher bandwidth and speed, which will help in Quantum Computing, Hypersonic Missile Defense Systems, and higher-level performance of Artificial Intelligence (AI); a function of Machine Learning and other sophisticated computing systems [6].

3.2 Radio wave communication system

Radio waves are electromagnetic waves with higher wavelengths ranging from 1mm to 100km and travel at the speed of light [7]. They are produced from accelerated charged particles [7]. It was first predicted by James Maxwell, demonstrated by Henrich Hertz, and practically implemented by Guglielmo Marconi [8]. For a radio signal to be detected e.g. FM radio station, an antenna must be used [9]. Generally for radio waves to be propagated, they need to be modulated. This modulation scheme may be phase, amplitude, or frequency modulation. Radio waves find their expression in everyday applications like Radio, TV, and Telecommunication. Since the Radio wave communication System finds its application in Radio and TV broadcasts, the trends observed in this sector are; Radio and TV apps which doesn't require reception via the antenna (thus making information accessible on the go), Internet radio, Live streaming of Radio and TV contents, etc. It is envisioned already that by the year 2030, mobile devices will support optical and radio technologies and Visible Light Communications (VLC), which will complement radio [10].

3.3 WI-FI communication system

Wi-Fi is a system, which creates a communication protocol that allows multiple device interfaces with the internet [11]. It makes use of the IEEE 802.11 radio technology. The Wi-Fi System works in such a way that multiple access points such as their service set identifier (SSID) are generated and sent forth as 'beacons', broadcasted as packets at about 1Mbit/s with devices connected to any of the available access points. The operational frequency of the Wi-Fi is between 2.4GHz and 5GHz with a bandwidth ranging between 11Mbit/s to 54Mbit/s [12]. As a result of the 5G network and later 6G network, technology has advanced to meet the demands of this latest networks. Recent trend shows that there has been the advent of Wi-Fi 5, Wi-Fi 6, and Wi-Fi 6E [13]. This hardware has been upgraded to satisfy the network requirements of higher bandwidth and latency-sensitive applications. Wi-Fi 6 and Wi-Fi 6E utilize the orthogonal frequency division multiple access (OFDMA) and target wake time (TWT) technologies. The former improves performance while the latter reduces and improves power consumption [14]. The future is the Wi-Fi 7 which will be much faster than the Wi-Fi 6E.

3.4 Radar communication system

Radio Detection and Ranging (RADAR) is a system designed to determine the angle, range, and speed of an object relative to a reference point in space. It was developed before World War II as means of detection. Depending on application objectives, it may encompass both the radio and microwave frequency bands and typically comprise a transmitter, antenna, receiver display unit, and duplexer. Radar systems, whose driving principles of operations are similar to light, can be either primary or secondary. Electromagnetic waves are transmitted, while the corresponding energy is used to determine the distance, speed, and direction of an object [15]. Talking about the evolution of this system, we now have a Radar system that is capable of detecting (mostly in aircraft) what, where, when, and how of the object in the study. The recent trends in radar systems are radar-permitting objects to be seen through the walls, and Lidar, which is advanced radar. More so, radar is likely to be as common as an application on mobile phones in the nearest future. The technology will evolve towards a 4D imaging radar capable of providing a dense 4D point cloud.

3.5 Bluetooth communication system

Bluetooth technology is a short-range in wireless communication between devices [16] such as mobile phones, Music Gadgets, Computers, and Personal Digital Assistants (PDAs) designed to operate within the radio frequency band. It was discovered in 1994 by Dr.Jaap Haartsen at Ericsson (a telecoms vendor), as an alternate means for data transfer between and among smart devices co-located within the same geographic space and the absence of a telecommunication network. Its connectivity range is between 10m to 100m and can connect up to seven devices at a time [17].

It leverages the Frequency Hopping Spread Spectrum (FHSS) consisting of 79 channels between 2402MHz to 2480MHz with 1MHz intervals [18]. Trends and evolution of Bluetooth technology include Bluetooth GPS tracking, AI sports, and health monitoring gadgets using Bluetooth as a result of the introduction of the 5G network [19].

3.6 Infra-red communication system

The infra-reds are one of the electromagnetic radiations residing between the ultra-violet and the microwave, having wavelengths between 700nm and 1mm. Similar to other radiations in the electromagnetic spectrum; it behaves like a wave and particle. Although the infra-red form of communication is a point-to-point, it is limited in distance. Therefore, transmitting information with the infrared on a large scale is not feasible because it requires repeater stations to travel a longer distance. Although over the years it has found its usage in Mobile Phones before the advent of Bluetooth and Wi-Fi technologies, it is however being gradually phased out in favour of communication that is more effective systems with similar operational objectives. Due to the obvious limitations of the Infra-Red, there are no trends in this system. In the future, infra-red technology will have photodetectors integrated with highly effective smart algorithms.

4. FUTURISTIC OUTLOOK IN COMMUNICATION SYSTEMS DEVELOPMENTS

The rapid increase in data-traffic consumption by users of modern community systems underscores the need to implement novel connectivity mechanisms that will guarantee acceptable levels of Quality of Service (QOS) reliability [20]. In this regard, the Bluetooth (Multi-Hop) relay technology in 5G wireless cellular networking, is projected to revolutionize future futuristic connection models, combining traditional centralized schemes, where users connect through the nearest Base Station (BS) relative to point of transmission/reception and the new paradigm of Device-to-Device network, which allows users to communicate peer-to-peer (P-2-P) through direct links, independent of Base Stations.

Conversely, optimization of the multi-hop scheme, which is subject to rapid degradation over very short distances over rapid power loss, holds the prospects of revolutionizing wider area coverage and communication systems enhancement. In this regard, transmission is further divided into a series of hops, using makeshift booster stations within the Bluetooth range (2402MHz to 2480MHz) to maintain relative gain between the transmitting and receiving devices, overcoming reduction in transmission power for links due to the non-linear nature of the path loss. The same applies to Wi-Fi and other modern communication systems.

Meanwhile, the consequences of this research are multifaceted. First, it provides a deeper understanding of the historical evolution of communication technologies, enabling insights into the societal impact of past innovations. Second, by analyzing current communication systems, the research facilitates a nuanced comprehension of contemporary trends and their implications across various sectors. Third, exploring the futuristic outlook allows for anticipation of emerging technologies, potential challenges, and transformative shifts in communication paradigms. Moreover, in terms of future directions, the research lays the groundwork for advancements in communication technologies, guiding innovations that align with societal needs. It informs policymakers and industry leaders on potential directions for regulation and investment. Additionally, the insights garnered from this research can contribute to the development of more resilient and adaptive communication systems, ensuring they remain effective in an ever-evolving technological landscape. Overall, the consequences and future directions of this research extend to shaping the trajectory of communication systems and their pervasive influence on society.

5. CONCLUSION

In this paper, a review of the trends and pattern developments in modern communication systems, including a robust futuristic outlook of development directions in the 5G network was undertaken. The work considered the rapid increase in data-traffic utilization over modern communication systems, which entails passing information from one point to the other and its various applications in the military, education, banking, commerce, finance, etc. The outlook dwelt on multi-hop communication systems, using repeaters to increase the coverage area of the network, which holds promise for communication systems operating on 5G as it relates to D-2-D communication. Meanwhile, given that operations of modern communication systems are continually geared towards the upper-frequency bands of the electromagnetic spectrum for greater efficiency, it is expected that significant attention will be paid to mitigating the impact of the path in traditional community and peer-to-peer (P-2-P) systems maximizing the use of innovative repeater models. In addition, there is a need for the formulation of optimum routing algorithms in expanding existential human dependence.

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