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Analysis and Comparison of the Three Widely Used Mobile Communication Technologies

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Abstract

This paper focused on the three competing mobile communication technologies, namely the global system for mobile communication (GSM), code division multiple access (CDMA) and world-wide interoperability for microwave access (WiMAX). The main problems that determine the quality of service rendered by the mobile operators to customers are accessibility, reliability, dropped calls, voice clarity and low connectivity. The method used comprised of forward link of digital modulation that transmitted signals from the base station to the mobile receiver and the reverse link that transmitted signals from the mobile transmitter to the base station. The results obtained indicated that the nominal bandwidth used for transmission from a base station to the mobile receivers was 1.25MHz with a separate channel having a bandwidth of 1.25MHz and these were used for the signal transmitted from mobile receivers to a base station. The comparison of these technologies was done with respect to their coverage, clarity, reliability, security, compatibility and traffic capacity. It was discovered that WiMAX appeared to be the best of the three when compared to the CDMA and GSM. WiMAX provides some relevant features such as speed, coverage, interoperability, non-line of sight (NLOS) requirement, superior quality of signals, reliability and accessibility. These features have made this technology more superior over the CDMA and GSM. The CDMA appeared to be the next choice with good spectrum conservation while the GSM has inherent frequent call dropping problems, unavailability, hard hand-off and unreliability. In conclusion, WiMAX technology offers a better choice for the next generation of wireless services with faster deployment of new users.

Keywords: *Spread spectrum, WiMAX, CDMA, GSM technology*

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1. Introduction

GSM, CDMA and WiMAX technologies are the three modern digital mobile technologies used in the world today. WiMAX is a telecommunication technology that provides wireless transmission of data using a variety of transmission modes, from point to multipoint links to portable and fully mobile internet access. The technology is of the Asian origin, a broadband wireless access based on the IEEE 802.16 standard. The CDMA technology is of the American origin based on spread spectrum technologies, while the GSM is of the European origin based on time division multiple access (TDMA) technologies (Ajayi et al., 2011). This comparative research work was done in order to find out the technical merits and demerits of these three technologies in order to determine the best mobile communications technology for Nigeria or any developing country in the world. This report therefore concerns the comparison of three mobile system technologies namely, the Global system for mobile communication, the code division multiple access and the latest wireless broadband technology, the worldwide interoperability for microwave access. The GSM, a second generation (2G) cellular solution employs digital technologies and protocols enabling users on the move to access telecommunication services. The second-generation GSM tri-band cellular phones provide digital services in the 900MHz and 1800MHz frequency bands in the European Union and in the 1900MHz bands in the United States. The GSM has a unique feature of short messages services (SMS) compared to the older analog systems (Baba et al., 2018).

The subscriber identity module (SIM) cards used by GSM only enable cell phones to get instantly activated, upgraded and swapped. The GSM's SIM card system is a novel approach that implements personal mobility in addition to terminal mobility and this is the international roaming feature and support for many other services amongst others. The modulation type employed in GSM is Gaussian minimum shift keying (GMSK), a kind of continuous phase/frequency shift keying (Bakare et al., 2017). The CDMA, a third generation (3G) technology is a digital interface standard, claiming eight to fifteen times the capacity of traditional analog cellular systems which is far more than the GSM. It presents greater security as compared to GSM/TDMA as it is more efficient in analog transmission. It has increased battery capacity; greater frequency reuse and the rate of call drop is reduced. The CDMA technology makes use of a modulation technique known as the Spread spectrum technique (Ezebuiro et al., 2013). The WiMAX, a fourth generation (4G) telecommunications protocol provides fixed and mobile internet services. The WiMAX provides broadband connectivity anywhere, anytime for any device and on any network. It offers the benefits of lower cost, wider coverage, higher capacity, and less power consumption. The WiMAX uses a modulation technique known as orthogonal frequency division multiple access (OFDMA) (Fazel and Kaiser, 2008).

The Nigerian communications commission (NCC) on 6th March, 2009 partnered with Nigerian WiMAX operator, ipWX to bring broadband access to all 36 states in the country through the state accelerated broadband initiative (SABI). The WiMAX has been considered a possible replacement candidate for cellular phone technologies such as GSM and CDMA or can be used as an over play to increase the capacity utilization of mobile services in Nigeria. Fixed WiMAX is also considered as a wireless backhaul technology for 2G, 3G and 4G networks in both developed and developing nations (Gumaidah et al., 2012). The GSM technology started in 1982 when the confederation of European posts and telecommunications (CEPT) formed the Groupe Speciale Mobile (GSM) to design a Pan-European mobile communications technology. The European commission endorsed the GSM project in 1984 and a year later, Italy, France, the UK and West Germany signed a joint agreement to develop the GSM. In early 1987, an agreement on the basic parameters of the GSM standard, the GSM memorandum of understanding (MOU) was promoted. Validation trials in 1988 proved that GSM technology was viable and in 1989 the Groupe Speciale Mobile became a technical committee within the European technical standards institute (ESTI) which helped to define GSM as an internationally accepted digital cellular telephone standard (Amit et al., 2010). The first GSM call in 1992 was placed in Finland and during the same year, the first SMS using GSM was sent. By 1993, 32 networks were using GSM in 18 different countries and by 1994 there were more than a hundred GSM operators and a million subscribers around the world. By 1996, the first GSM networks were deployed in Russia and China. In 1997, the USA alone had 15 million GSM networks and by 1998 there were over a hundred million GSM subscribers globally. In 1999, the GSM gained another layer called the wireless access protocol (WAP). Today the GSM spans over all countries in the world with the penetration of billions of users (Baba et al., 2018). The CDMA has a history that goes back to the early days of World War II. The idea which was known as frequency-hopping and later as frequency-hopping spread spectrum technology remained dormant until 1957 when engineers at the Sylvania electronic system division in buffalo, New York took up the idea. In 1989, a company called Qualcomm began to point out advantages of CDMA over GSM. The industry body, the cellular telecommunications industry association (CTIA) initially gave the CDMA proposal a lukewarm reception and by 1991, Qualcomm had persuaded American telecommunications companies to undertake a large-scale test of the CDMA technology. In 1993, the CTIA accepted CDMA as an American mobile communications standard (Ajayi et al., 2011).

In the mid 1990's telecommunication companies in Asia developed the idea to use fixed broadband wireless networks to provide an alternative means to deliver internet connectivity to businesses and individuals (ITU Report, 2009). Their aim was to produce a network with the speed, capacity, and reliability of a hardwired network, while maintaining the flexibility, simplicity, and low costs of a wireless network. This technology would also act as a versatile system for corporate or institutional backhaul distribution networks and would attempt to compete with the leading internet carriers. In 1999 the Institute of electrical and electronics engineers (IEEE) devised the 802.16 standard for local multipoint distribution service (LMDS). This standard, which was eventually released in 2001, operated on a point-to-point radio link network by means of line-of-sight transmission and had a frequency range of 10 GHz to 66 GHz. However, since this standard was modelled on wireless local area network (WLAN) technology and had restricted capacities, developers focused more exclusively on the 802.16 standard that functioned in the range of 2GHz to 11GHz (Rakesh and Sing, 2012). In 2001, the WiMAX forum was established with the agenda to market and promote the 802.16 standard and WiMAX was coined as worldwide interoperability for microwave access. In 2003, the IEEE came out with 802.16a, which transmitted data through non-line of sight radio channels to and from Omni-directional antennas. Later on, in 2004, the 802.16 - 2004 standards were released. This standard combined the updates from the IEEE 802.16a, 802.16b, and 802.16c regulations. This broadband system extended the WiMAX service to a 30-mile range and had the ability to disperse its network between hundreds of terminals. Yet the IEEE did not stop there. In 2005, the first mobile WiMAX system came out, 802.16e. This version used a scalable Orthogonal Frequency-Division Multiple Access (SODMA) engine, which supported over 2,000 subcarriers, optimized handover delay and packet loss, and increased network security (Patidar et al., 2012). The IEEE continues to update and modify the WiMAX system specifications to further improve its capabilities. Their next major 802.16 standard named 802.16m was published. One of the goals for this version is to increase data speeds to 1Gbps (Pareit et al., 2012). IEEE also looks ahead to approve and deploy the 802.20 standard in the near future, which has dubbed the nickname Mobile-Fi. Many WiMAX forums certified products for fixed and nomadic applications are currently commercially available and are constantly being developed.

2. Materials and methods

2.1 Materials

The materials required for this paper are convolution encoder, code generator, filters, transmitter, receiver, decimator, detector and Hadamard sequence. The purpose of a convolutional encoder is to take a single or multi-bit input and generate a matrix of encoded output codes. Also, it is a process of adding redundancy to a signal stream. The code generator converts the intermediate representation of source code into a form that can be readily executed by the machine. The receiver is a circuit that accepts signals from a transmission medium and decodes them into a form that can drive local circuits. The receiver recovers the information from the received signal in the antenna. The transmitter is use to transmit the carrier signal modulated by information through an antenna. The decimator is useful in applications in which the Nyquist frequency of a signal is much higher than the highest frequency of the signal. The Hadamard sequence is used to transmit a pilot signal which serves as a means of measuring the channel characteristics including the signal strength and the carrier phase offset. Filters are used to remove unwanted frequency components from the applied signal and enhance wanted signals. The detector is a device that converts an amount of radiation into some other measurable phenomenon.

2.2 Method

The method adopted make use of the forward and reverse links of a digital modulation system. The forward link of the modulator was transmitted from a base station to the mobile receiver with the speed coder which generates data at the variable rates of 9600, 4800, 2400 and 1200bits/sec. The data from the speech coder was coded by a rate of half and constraint length of nine convolutional codes. The encoded bits for each frame was passed through a block interleaved which was needed to overcome the effects of burst errors that can occur in transmission through the channel. The data bits at the output of the block interleaved occurs at a rate of 19.2Kbits/s and a long code was used to identify a call from a mobile station on the forward and reverse links. Each user of the channel was assigned a Hadamard sequence of length 64 and there are 64 orthogonal Hadamard sequence assigned to each base station. These parameters were used by the receiver in performing phase coherent demodulation and time synchronization with one channel used for paging. Again, each user that used the Hadamard sequence assigned to it multiples data sequence of length 64. The resulting binary sequence was spread by multiplication with two sequences to create in phase and quadrature signal components. In the reverse link, the signals which was transmitted from the various mobile transmitters to the base stations were synchronous and there was more interference among users since the mobile transmitters are battery operated. To reduce interference, the time position of the transmitted code symbol repetitions was randomized so that at the lower speech activity, consecutive bursts do not occur in time. The signal was spread by the output of the long code generator which runs at a rate of 1.2288MChips/s. There were only four chips for every bit of the Hadamard sequence from the modulator so that the processing gain in the reverse link was minimal. The demodulator employs non coherent demodulation orthogonal Hadamard waveforms to recover the encoded data bits. The output of the demodulator was then fed to the Viterbi detector whose output was used to synthesize the speed signal.

Let assume that the interference on the channel is characterized as additive white Gaussian noise (AWGN) with power spectral density I_d. Therefore, the probability of error P_x for the detection on non-coherently demodulated binary frequency shift keying is given in Equation (1).

$$P_x = \frac{1}{2} e^{-\rho_b/2} \quad (1)$$

where $\rho_b = E_b/I_d$ is the SNR/bit. The energy/bit, E_b can be written as shown in Equation (2).

$$E_b = P_t T_b = \frac{P_s}{R_o} \quad (2)$$

where P_t is the average transmitted power, T_b is the broadband frequency and R_o is the bit rate.

Again, $I_d = P_I/N$ (3)

where P_I is the average power of the broadband interference and N is the available channel bandwidth.

The signal-to-noise ratio ρ_b is given in Equation (4).

$$\rho_b = \frac{E_b}{I_d} = \frac{N/R}{P_I/P_t} \quad (4)$$

Where N/R_O is the processing gain and P_I/P_t is the interference margin for the frequency hopping spread spectrum signal. In the region where the power-spectral density is non zero, its value is given as:

$$S_I(f) = I_d/\beta \quad (5)$$

where $0 < \beta \leq 1$.

With binary frequency shift keying modulation with no coherent detection, the transmitted frequencies are selected with uniform probability in the frequency band (N).

As a result, the received signal will be corrupted by interference with probability β. When the interference is present, the probability of error is $1/2\, e^{-\beta\rho_b/2}$ and when the interference is not present, the defection of the signal is assumed to be error free.

However, the average probability of error is as shown in Equation (6).

$$P_x(\beta) = \frac{\beta}{2} e^{-\beta\rho_b/2} = \frac{\beta}{2}\, e^{\frac{\beta N/R_O}{2P_I/P_t}} \quad (6)$$

By differentiating $P_x(\beta)$ and solving for the value of β that maximizes $P_x(\beta)$, it is shown in Equation (7) that:

$$\beta' = \begin{cases} 2/\rho_b, & \rho_b \geq 2 \\ 1, & \rho_b < 2 \end{cases} \quad (7)$$

The corresponding probability of error for the partial-band interference is given in Equation (8).

$$P_x = \begin{cases} e^{-1}/\rho_b, & \rho_b \geq 2 \\ 1/2\, e^{-\rho_b/2}, & \rho_b < 2 \end{cases} \quad (8)$$

2.3 WiMAX requirements for high level architecture

There are numerous types of requirements that relates to WiMAX reference architecture. These are the support of roaming and interworking with fixed and mobile networks. The support includes complete scale of services, applications and a very high-performance packet based network that ensure maximum flexibility based on standard protocols. Again, there are other types of requirements needed to support WiMAX in terms of applications and services. These involves the interfacing with a variety of interworking and media gateways that translates legacy services to internet protocol and transport them over WiMAX radio access networks. Also, it ensures the use of multimedia, voice, emergency calls and the delivery of internet protocol, multicast and broadcast services (Kamali et al., 2012). The requirements for network internetworking and roaming involves the deployment of global roaming between WiMAX operators. The diversity of user authentication methods like username, digital certificates, password and the loose coupling with current wired or wireless networks.

2.4 Internet core network functions

Multiple users can be integrated into the WiMAX service value chain for ease and accessibility to connection in the architectural framework. This can be implemented using the recommended hierarchies. This includes the network reference model developed by the WiMAX forum network working group and the network access provider which can operate the access service network. Again, the network service provider provides internet protocol connectivity and WiMAX services to subscribers using the access service network infrastructure. Furthermore, the application of a service provider provides value added services such as multimedia applications using internet protocol multimedia subsystem, corporate virtual and the private networks. (Khan and Igbal, 2014).

3. Results and discussion

The results obtained during the analysis and comparison of these three technologies were based on numerous areas such as handoff, power control, efficiency, interference, large open coverage, services, reliability, call drops, system modulation and spectrum. In WiMAX access, the handoff requirements should be fast enough in the order of 50ms or 150ms. The handover needs some security requirements since some attacks are possible at the occasion of the handover procedure. The WiMAX has a very soft handoff since there is no mast and towers for signal transmission. In CDMA, when the mobile call moves into a different cell while a conversation is in progress, the switching center automatically transfers the call to the new base station. This handoff operation did not only involves identifying a new base station but also requires the signals that can be allocated to the channel. The CDMA also has a soft handoff for signal transmission while the GSM operates with a hard handoff for signal transmission. In WiMAX, when the received signal was measured at the base station, the base station sends power offset indications to the mobile station. When the mobile station uses only a portion of the sub channels, the power density remains unchanged regardless of the number of sub channels used. The power offset was consistent with the maximum power that the mobile station can transmit. It has less power requirement with a typical mobile transmit power of less than 200MW. In CDMA, to maximize the total user capacity of the system in the forward link, the power of the signal received from each of the users over the forward link must be made nearly equal. Also, if the received signal is weak, the user will be dropped and if the received power of the signal is strong, the performance of the received signal will be accepted. For the reverse link, the transmitted power can be adjusted individually by measuring the forward link power received by the mobile receiver. The higher the received signal power, the lower the transmitted power and vice versa. It operates with low power requirements and mobile transmit power of less than 200MW. The GSM works with high power at the base stations and mobile transmit power of less than 200MW.

The effect of co-channel interference in WiMAX is avoided through frequency planning and the same frequency equipment work together. In CDMA, the effect of co-channel interference is less and avoided through site selections. In GSM, the effect of co-channel interference competes with the needed signals and interferes with some electronics devices. WiMAX provides wide coverage area and exhibits 10mbps at a distance of 10km within line-of-sight propagation. The CDMA work very well in large open coverage area and its range of communication is extended to rural users situated away from the base stations. The GSM has unstable audio signal and a fixed maximum cell site range of 120km radius which poses technical limitations to coverage area. The WiMAX system provides high spectral efficiency data rates to users. High spectral efficiency and performance superiority over radio systems is achieved by the use of advanced antenna technology systems and multiple input multiple output systems. WiMAX has a reliability of up to 100%. The CDMA has a reliability of a little bit less than 100% while the GSM has a reliability of much less than 100%. WiMAX make use of digital modulation to modulate an analogue signal with a digital sequence in order to transport digital sequence over a given medium. These modulations are BPSK, QPSK, 16-QAM and 64-QAM. CDMA systems concentrates on the communication aspects such as modulation and coding of spread spectrum signals in the transmitter and the reverse operations at the receiver. The GSM system uses the Gaussian minimum shift key (GMSK) modulation. The WiMAX system is the most recent and advanced technology that has a lot of advantages over the other two such as the use of strong encryption codes, higher capacity, large area coverage, well reduced health risk, access to voice call, data rate, e-business, e-commerce, video and internet services, and most importantly interoperability and connectivity with other mobile communications networks. The CDMA system offers good range of services such as reliability, longer battery life, soft handoff, good compatibility with existing and future technologies, reduced noise and interference compared with the GSM that has the best international roaming capability, largest world coverage subscriber based due to early commercialization. The GSM has inherent calling dropping and unavailability problems.

4. Conclusion

The security in WiMAX protects the traffic confidentiality, integrity and enhance network security. The privacy key management protocol is included in the standard security sublayer to provide secure distribution of keying data from the base station to the mobile station. Several encryption algorithms are used for securing ciphering key exchange and for the encryption of transport data. To provide wireless communication, the base stations should be connected to the switching center which provides connectivity between the public telephone network and all the users in a system. With CDMA, universal frequency reuse applies to all users in the same cell and those in adjacent cells. The result of the comparison between GSM, CDMA and WIMAX mobile technologies was analyzed, thereby highlighting the strong and weak points. However, from the major findings of this study, it is shown that the WiMAX appears to be best choice of technology compared with the other two.

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