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1 Performance Comparison of Cellular Mobile Communication Systems and their Implementation in Yemen

Abdulla Saeed Bin Ghouth*

Abstract

Analog cellular systems are the first generation of cellular systems. These systems use analog frequency modulation (FM) and have a frequency division multiple access (FDMA) based media access control architecture. Second-generation cellular systems primarily use digital modulation and processing techniques and time division multiple access (TDMA). As of 1995, several million TDMA digital cellular subscriber units are operational. These second-generation systems include the GSM (Global system for mobile communications), ADC (American digital cellular IS-54 Standard and JDC, Japanese digital cellular.

Third –generation systems using spread-spectrum techniques like code-division multiple access (CDMA), have also been standardized and are now operational in many countries. System and equipment development in the US led to the adoption of the IS-95 standard for cellular digital communication in the 900 MHz frequency band.

In Yemen, mobile communications started by Tele-Yemen company in the 1990s, using FDMA systems. In the year 2000, two other companies, Sabafon and Spacetel started their GSM service and it is now covering great part of the country. The government also introduced some isolated mobile services in rural areas.

The aim of this paper is to study second- and third-generation cellular systems which are operating or likely to operate in Yemen and to investigate the performance of these systems. The comparison reveals that CDMA and spread-spectrum systems are superior and suitable for new generations of system applications.

Keywords: Cellular mobile, GSM, CDMA, Performance.

الملخص

إن الجيل الأول من أنظمة الاتصالات المحمولة كان نظاما تماثليا و يستخدم التضمين النبضي و كذا التقسيم الطيفي للقنوات المختلفة. أما الجيل الثاني من الأنظمة فهو يستخدم نظام التضمين الرقمي و المعالجة الرقمية و يكون توزيع القنوات فيه إما بواسطة التقسيم الطيفي FDMA أو التقسيم الزمني TDMA. حتى عام 1995 كان هناك ثلاثة أنظمة للجيل الثاني:

- النظام العالمي للاتصالات عبر المحمول GSM
- النظام الرقمي الأمريكي ADC
- النظام الرقمي الياباني JDC

* Electronics and Communications Engg. Department, Faculty of Engineering, University of Aden, Yemen
E – mail aboyasser_a@Yahoo.com

الجيل الثالث من الأنظمة تطور من النظامين الأمريكي و الياباني و هو يستخدم نظام توزيع القنوات بواسطة الشفرات و أنظمة النطاق الترددي العريض. و ابتداء من عام 1995 تم تطوير مواصفات فنية موحدة لهذا النظام CDMA في نطاق الحزمة 900 ميجاهرتز مع إمكانية تطويره إلى نطاق الحزمة 1900 ميجاهرتز لنظام الاتصالات الشخصية. و قد بدأ الاستخدام التجاري لهذه الخدمة في الولايات المتحدة عام 1998.
في اليمن تم إدخال خدمة المحمول بواسطة شركة تيليمن في التسعينات من القرن الماضي باستخدام أجهزة الجيل الأول. و في عام 2000 تم السماح لشركتي سبأفون و سبيستل يمن بتشغيل الخدمة الهاتفية المحمولة بواسطة أنظمة الجيل الثاني GSM و قامتا بتغطية أجزاء كبيرة من القطر اليمنى. في نهاية عام 2004 أدخلت الخدمة بنظام CDMA بواسطة الشركة الحكومية يمن موبايل كما تنوى الحكومة السماح لمشغل رابع بنفس النظام.
تهدف هذه الورقة لمقارنة أنظمة الهاتف المحمول الخلوية التي تعمل في اليمن و هي GSM و تطويراته المختلفة و CDMA (المرحلة الأولى) و المراحل اللاحقة من الناحية الفنية ووفق مواصفات معينة ناقشتها الورقة. و قد خلصت إلى أن نظام CDMA أفضل من ناحية التطبيقات العملية و التطويرية اللاحقة مع أمكانية تطوير GSM للقيام ببعض هذه التطبيقات.

1. INTRODUCTION

The cellular concept began to appear in Bell system proposals during the late 1940s. This idea introduced a new model for mobile radio in which the ‘ broadcast model’ of a high power transmitter, placed at a high elevation, transmitting the signal to a large area was replaced by many lower-power transmitters, each specifically designed to serve only a small area called a cell. The same frequencies (channels) could be reused in different cells with sufficient distance, where the effect of interference between users of the same channel was negligible. The important features of cellular systems are [Feher, 1999]:

- Low power transmitters and small coverage zones.
- Frequency reuse.
- Cell splitting to increase capacity.
- Hand-off and central control.

In December 1971, the Bell system submitted a proposal for a new analog cellular FM radio system – The High Capacity Mobile Telephone System (HCMTS). The Federal Communication Commission accepted the proposal and a spectrum of 40 MHz in the 850-MHz band was allocated for this system. The US analog standard of the 1980s and 1990s for cellular radio- Advance Mobile Phone Service (AMPS) – evolved from the HCMTS. Several other similar systems were developed in Europe and elsewhere but there was no worldwide standard for the cellular service at that time. These first generation cellular systems suffer from two drawbacks: capacity limits as the system become more popular and incompatibility which makes it impossible for a person to use the same cellular phone in different countries.

These limitations motivated the development of second-generation cellular systems with the goal of achieving higher capacity and improved compatibility. The second-generation systems are all digital and most of them have a TDMA access mode [Randy, 1996]. The early ones conform to at least three main standards: The GSM for Europe and international applications; the North America, IS-54 and the Japanese Digital Cellular (JDC). These systems are in operation since early 1990s. In 1995, the first CDMA system was developed in US, called IS-95, and subsequent developments led to the third generation CDMA systems.

Third-Generation cellular systems are advanced time division multiple access (TDMA), code division multiple access (CDMA), Spread-spectrum and narrow-band digital frequency division multiple access (FDMA) system architecture. The evolution towards the third generation wireless networks is to support the high data rates specified by the International Telecommunication Union.

In Yemen, modern cellular system service was introduced by Sabafon and Spacetel companies during the year 2000 using a GSM-based system. Recently Yemen Mobile system is launched by the ministry of communications and Information Technology which introduced the CDMA2000 1x as the first third generation system. In this paper we will look into the performance of the GSM as an example of a TDMA-access second-generation system and the CDMA2000 and its variance as an example of the third generation systems.

2. THE GSM SYSTEM

The GSM was originally developed by a study group called ‘ Group Special Mobile’, appointed by the Conference of European Post and Telegraphs in 1982. The aim of the group was to develop a pan-European public land mobile system. In 1989, GSM responsibility was transferred to the European Telecommunication Standards Institute (ETSI) and phase1 of the GSM specifications was published in 1990. Commercial service was started in mid 1991. Although it was standardized in Europe, GSM is not only an European standard. Over 200 GSM networks are operational in 110 countries around the world. In 1997, there were more than 55 million subscribers worldwide. GSM system exists on every continent and the acronym GSM now stands for Global System for Mobile Communication.

The GSM system uses the frequency range 890-915 MHz for the uplink (mobile station to base station) and 935-960 MHz for the downlink (base station to mobile station). This bandwidth is shared by users using a method, which is a combination of Time-and Frequency Multiple Access (TDMA/FDMA). The FDMA part involves the division by frequency of the 25 MHz bandwidth into 124 carrier frequencies spaces 200 KHz apart. One or more carrier frequencies are assigned to each base station. Each of these carrier frequencies is then divided in time, using a TDMA scheme. The fundamental unit of time in this TDMA scheme is called a burst period and it lasts approximately 0.57ms. Eight burst periods are grouped into a TDMA frame (lasts 4.6 ms), which forms the basic unit for the definition of logical channels. One physical channel is one burst period per TDMA frame.

Speech coding in GSM uses regular pulse excitation – long term prediction coding with a bit rate of 13 Kbps. Convolutional encoding and block interleaving is used to protect data from errors. Each time-slot burst is transmitted at a gross bit rate of 270.8 Kbps. This digital signal is modulated onto the analog carrier using Gaussian-filtered Minimum Shift Keying (GMSK). GMSK was selected as a compromise between spectral efficiency,

complexity of the transmitter, and limited spurious emissions. Slow frequency hopping is also used to reduce multipath fading. Discontinuous transmission and reception is used to minimize co-channel interference and conserve power at the mobile station.
The original GSM supports the following services:

1. Telephony
2. Data services at a rate of 9.6 Kbps
3. Group 3 facsimile, which is supported by use of appropriate fax adapter.
4. Short message service (SMS) – up to 160 byte messages.

2.1 GSM Evolution

- GSM networks will enhance packet data services primarily in three phases. General Packet Radio Services (GPRS) refers to the first phase of GSM network architecture enhancements that allow mobiles to connect to IP or X.25 based networks.
- The GSM/GPRS network architecture will further evolve to support Enhanced Data Rates for GSM Evolution (EDGE), which provides significant improvements over GPRS.
- Finally, the ETSI/ARIB Wideband CDMA (WCDMA) proposal provides a new air interface for GSM networks – supporting higher data rates that meet the ITU specifications.

3. CDMA SYSTEM

Code division multiple access (CDMA) spread spectrum technique was first introduced in USA [Feher 1999] as the IS-95 CDMA standard of the Electronic Industry Association (EIA) and the Telecommunication Industry Association (TIA) (EIA/TIA, 1993). The system and equipment development, pioneered by Qualcomm,Inc., led to the adoption of the IS-95 standard for cellular digital communications in the ‘ 900 MHz ’ frequency band, and it has been proposed for consideration as a potential personal communication system (PCS) standard for 1.9 GHz wireless application. Some of the unique features of CDMA, such as high system capacity, low transmit power, multipath mitigation, soft hand-off, and uniform coverage, make CDMA suitable for new generations of system applications.
The reverse CDMA channel (from the mobile units to the base station) is composed of access channels and reverse traffic channels. These channels share the same CDMA frequency assignment using direct-sequence CDMA techniques. Each traffic channel or access channel is identified by a long distinct user code. Multiple reverse CDMA channels may be used by a base station in a frequency-multiplexed manner.
The baseband modulation used in CDMA [Randy 1996] is an offset Quadrature Phase Shift Keying. Data transmitted on the reverse CDMA channel is grouped into 20-ms frames. All data transmitted is convolutionally encoded, block-interleaved, modulated by means of 64-ary orthogonal modulation, and direct-sequence spread prior to transmission. Data frames may be transmitted at a data rate of 9600, 4800, 2400 or 1200 b/s while the rate of the spreading is fixed at 1.2288 Mcps.

3.1 CDMA Evolution

The IS-95 standard was upgraded to IS-95A in 1995. In 1998, the IS-95B was introduced to increase the bit rate eight times. In the year 2001, CDMA2000 1x was implemented having a bit rate of 153.6 kbps. This is considered to be a third-generation system. Higher bit rate systems are expected to evolve in the next few years which provide the users with broadband capabilities via their cell phones, PDAs, and other mobile devices, enabling extremely high speed Internet connectivity at ten times the speeds provided by current CDMA2000 1x and GPRS solutions while simultaneously supporting the voice capability of CDMA2000 1x.

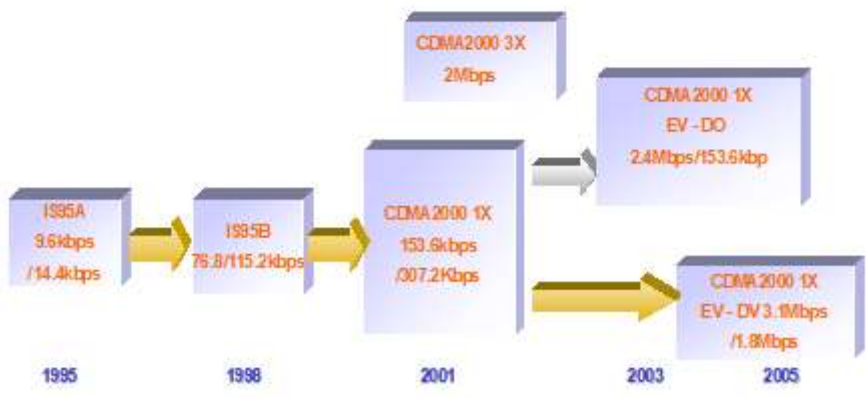

Fig. 1 Evolution of CDMA systems

4. COMPARISON BETWEEN GSM AND CDMA2000 1X

In this section, we will compare the GSM system and the recently introduced CDMA2000 1x, since these two systems are currently co-existing services in Yemen. The comparison is based on the following:

1. The most important parameter in mobile systems which is the spectrum efficiency. This parameter determines the capacity of the system, i.e. the total number of subscribers accommodated by the system in a certain bandwidth.
2. High- Speed data capability
3. Transmitter power
4. Receiver sensitivity
5. Coverage capability
6. Ability of the system to evolve, supporting new applications.

The following table compares the capacity of the two systems in 5 MHz bandwidth.

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Table (1): Comparison Between GSM and CDMA2000 1X in 5 MHz Bandwidth

Items	GSM	CDMA2000 1X
Channel bandwidth (MHz)	0.2	1.25
TRX number	25	3
Max. configuration of single BS(TRX)	9	9
Channels of single TRX	8	45
Simultaneous users of one BTS	66	405
Capacity supported (0.02Erl) of one BTS	2,300	18,000

The capacity (Spectrum Efficiency) of CDMA2000 1x is 6~7 times of that in GSM

Table 2, gives the technical comparison between the two systems

Table (2): Technical Comparison

Item	CDMA2000 1x	GSM
Spectrum Efficiency	Best (18000Subs/5MHz)	Good (2300Subs/5MHz)
High-Speed Data Capability	Best (153kbps)	Good (GSM 10kbps, GPRS 114kbps)
Coverage Capability	Best	Good
Receiving sensibility	BS: -128 dBm MS: -105 dBm	BS: - 110 dBm MS: - 102 dBm
Transmit power	BS: 20W MS: 200mW	BS: 20W MS: 2W
Multiple Bands Availability	Best 450M/800M/1900M/2100M	Good 900M/1800M/1900M
Evolution to 3G	Best (1x -> DO -> DV)	Good (GSM ->GPRS/EDGE ->WCDMA)

5. CONCLUSION

Since, in Yemen, we have the original GSM system and the incoming CDMA2000 1x as the two existing systems, comparison reveals the following points:

1. CDMA2000 1x has more spectrum efficiency than GSM in the same bandwidth.
2. High-speed data capability is best with CDMA2000 1x. However, upgrading the GSM system with GPRS will allow it to compete with the CDMA.
3. Mobile station power consumption of the CDMA2000 1x is less than that of GSM. This feature is important for longer battery life.
4. Both systems have the capability of evolution to third-generation higher systems.

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