Multiple Access Techniques: Design Issuesin FDMA/TDMA

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Introduction

- According to Cisco Visual Networking Index (2016), cellular networks currently support more than **eight** (***8)billion mobile users***.
  - More than *half a billion (**563 million**)* were added in 2015 alone.
- With the advent of Internet of Things (IoT) and smart applications,
  - At least ***8.2 billion handheld or personal mobile-ready devices*** and ***3.2 billion M2M connections*** are expected to be connected by 2020 as shown in Fig. 1 and Fig. 2.

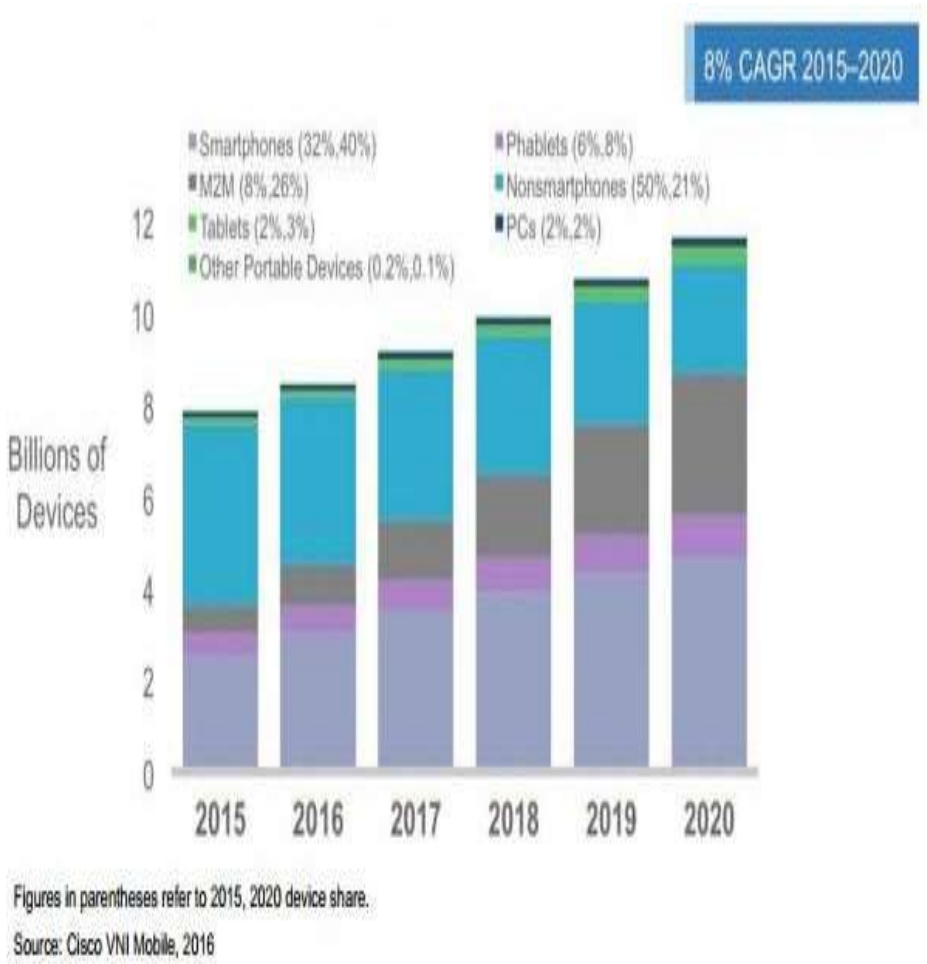
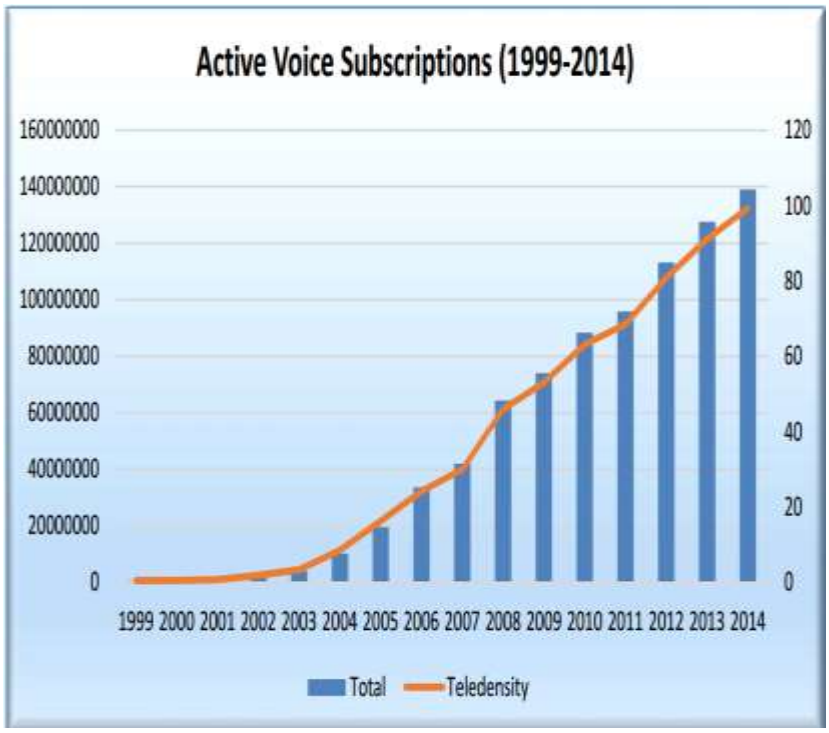


Fig. 1: Growing Trends of Mobile Devices across the World



Source: Nigerian Communications Commission (2015)

Fig. 2: Growing Trends of Trend of Active Voice Subscriptions in Nigeria

Table 1: Installed Capacity, Active Voice Subscription, and Base Station Data for GSM in Nigeria

	Installed Capacity		Active Voice Subscription		Base Stations	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**
MTN	80,000,000	80,000,000	56,766,085	59,893,093	11,551	12,557
GLO	39,396,740	38,631,800	25,933,867	28,219,089	6,305	6,677

AIRTEL	58,000,000	51,012,668	24,847,567	27,556,544	5,997	6,186
ETISALAT	40,000,000	40,000,000	17,035,276	21,103,749	4,436	4,756
TOTAL	**217,396,740**	**209,644,468**	**124,582,795**	**136,772,475**	**28,289**	**30,176**

Source: Nigerian Communications Commission (2015)

Problem of Spectrum Scarcity in Wireless Communication

- Today, frequency spectrum has become a scarce networkresource in wireless communication
  - Unprecedented growth in wireless devices causes spectrum congestion

Table 2: 900/1800 MHz GSM Frequency Allocation Table

900 MHz GSM Band Assignment					
	ETISALAT	**MTEL**	**GLO**	**MTN**	**AIRTEL**
Tx (MHz)	935-940	940-945	945-950	950-955	955-960
Rx (MHz)	890-895	895-900	900-905	905-910	910-915
1800 MHz GSM Band Assignment					
	MTEL	**GLO**	**MTN**	**AIRTEL**	**ETISALAT**
Tx (MHz)	1805-1820	1820-1835	1835-1850	1850-1865	1865-1880
Rx (MHz)	1710-1725	1725-1740	1740-1755	1755-1770	1770-1785

- *Migration of fixed wireless communications to cable or optical fiber* and assign released blocks of spectrum to mobile communications.
- Use of *new spectrum in the higher frequency bands*
  - Microwave frequencies (300 MHz – 30 GHz)
  - Millimeter wave frequencies (30 – 300 GHz)

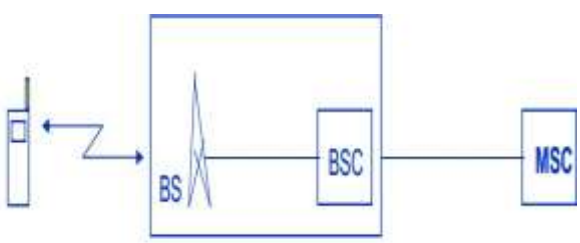
- Efficient use of available spectrum
  - This involves the adoption of efficient techniques that allows as many users as possible on limited spectrum band.

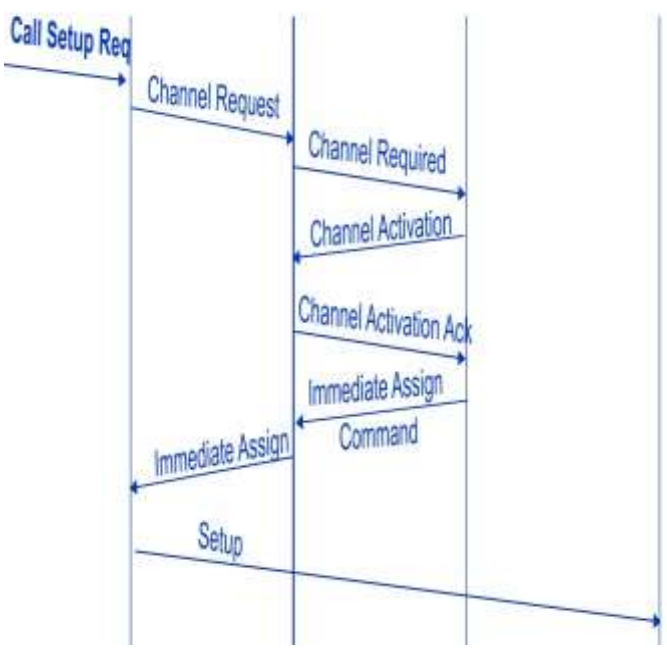
✓ Channel efficiency – this relates to signal and modulation

✓ Spectral efficiency – this relates the number of channels that can be obtained from a given bandwidth.

- This can be defined as the number of users that can share a given bandwidth in a unit area i.e. user/MHz/Km^2 while meeting the grade of service (GoS) specifications.
- Factors that determines overall spectrum efficiency
  - Cell size;
  - Low rate voice encoder;
  - Channel bandwidth;
  - Frequency reuse factor; and
  - *Multiple access*.

- Multiple access techniques allow many mobile users to use a common limited spectrum band in a more efficient manner.
  - Mobile terminals send access request to base stations through ***random access channels***.
  - If there are available ***message channels***, base stations grant permission through ***paging channels***, and assign a free pair of channels.





- As the mobile terminal receive the channel allocation message, it tunes to the assigned channels:
  - one for *forward link*; and

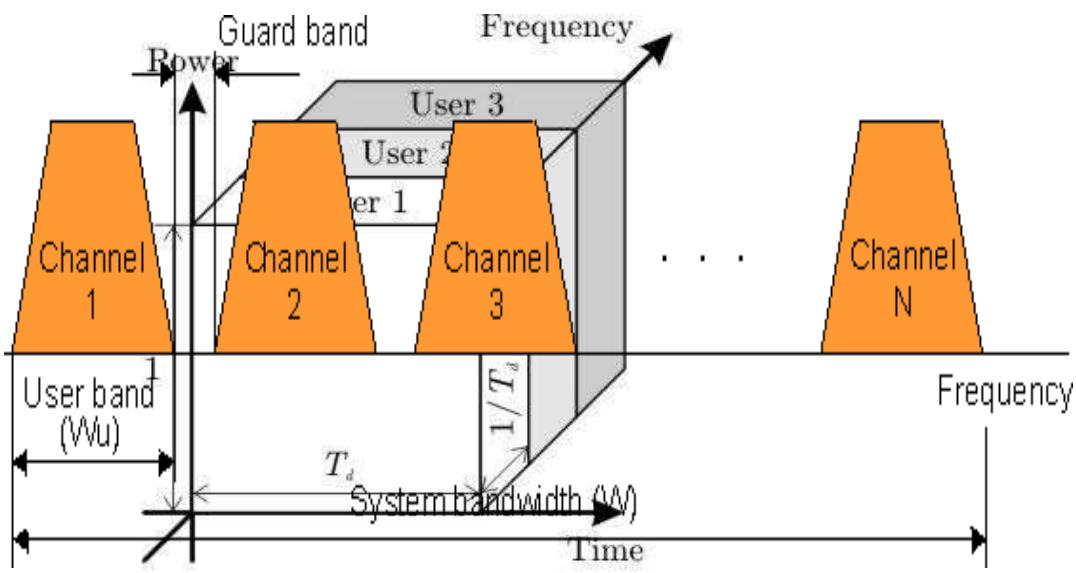
- the other for *reverse link*.

- It then sends acknowledgment message to the base station using the assigned reverse link.

- The way the message channels are arranged depends on the multiple access technique employed which may be:

  - Frequency Division Multiple Access (**FDMA**);
  - Time Division Multiple Access (**TDMA**);
  - Code Division Multiple Access (**CDMA**); or
  - Orthogonal Frequency Division Multiple Access (**OFDMA**)

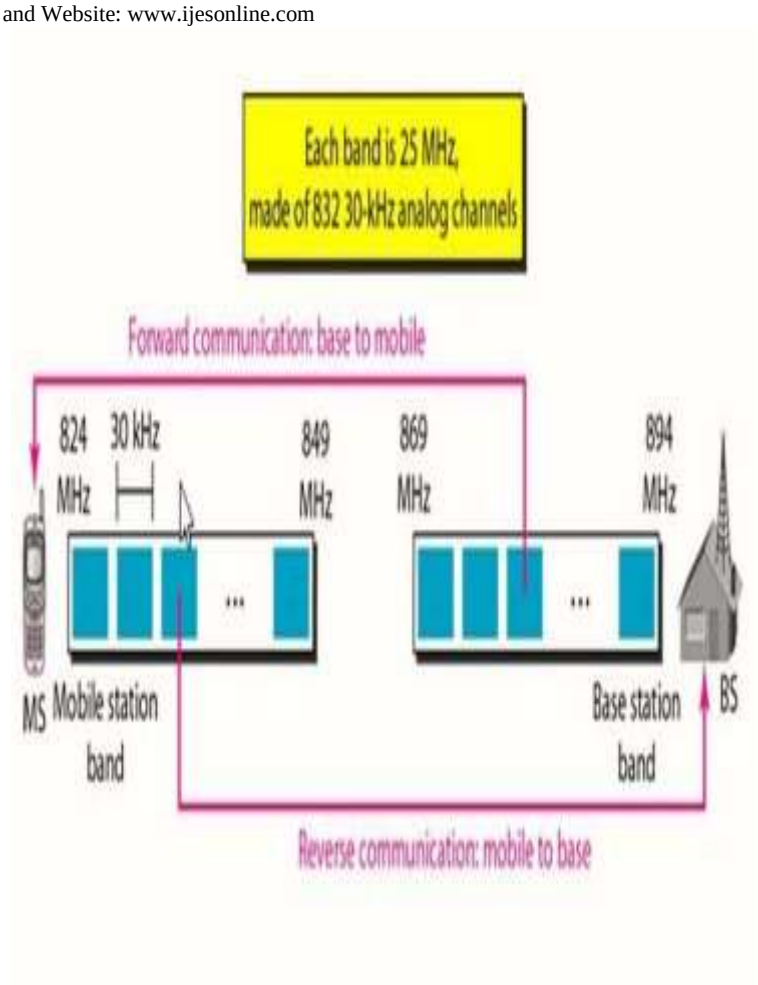
- FDMA divides available bandwidth into a number oforthogonal channels of smaller bandwidths.



FDMA

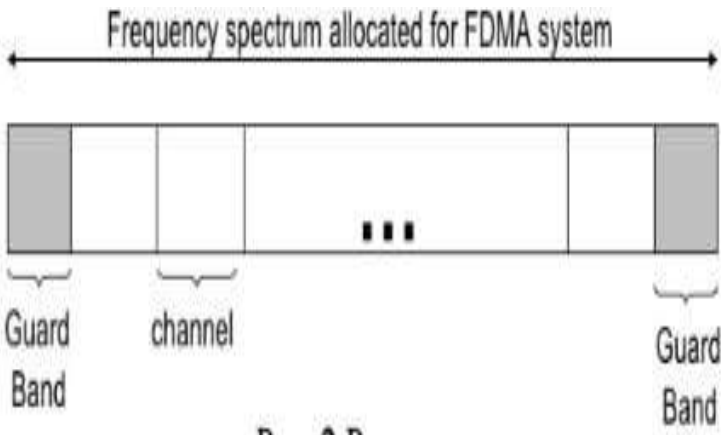
- A channel is used continuously over the duration of the message.
- FDMA is limited to narrowband applications due to its limited transmission rate.
  - If the same channel is reused at another physically separate location, an increase in transmit power will negatively affect the carrier-to-interference ratio at thatlocation.

- FDMA is employed in first generation cellulartechnology
  - Advanced Mobile Phone Systems (AMPS)
- A total bandwidth of 50 MHz is divided equally into two:
  - 25 MHz for forward link; and
  - 25 MHz for reverse link.
- 12.5 MHz each is allocated to two competing networkoperators.



- In AMPS, a **channel bandwidth** of **30 kHz** anda total of **832 channels** are available.

- A **guard band** of **10 kHz** is allowed at theedge to reduce inter-system interference.



$$N = \frac{B_t - 2B_{guard}}{B_c}$$

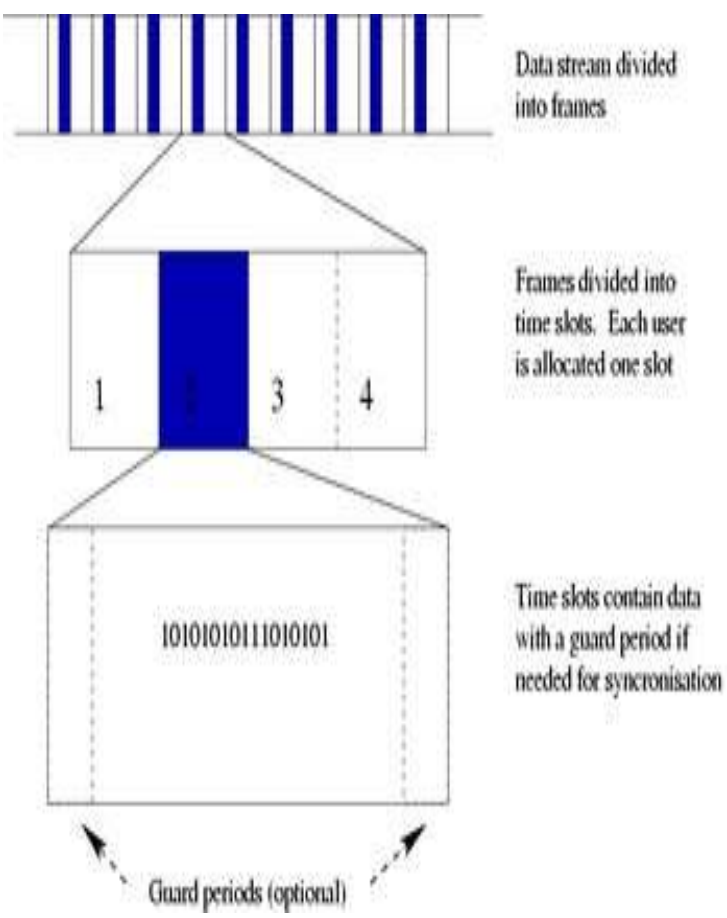
B_t : Total spectrum allocation

B_{guard}: Guard band allocated at the edge of the spectrum band

B_c : Bandwidth of a channel

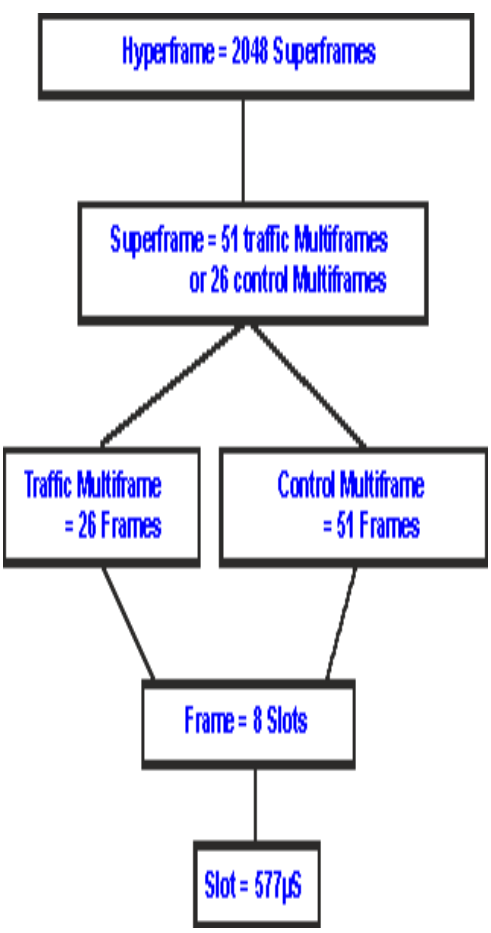
- *Low Inter-Symbol Interference (ISI)*
    - It has significant channel delay spread relative to the symbol period because thetransmission bandwidth is wider than thechannel coherence bandwidth.
- *Lower Overhead*
    - FDMA system uses channels on a continuous basis thereby periodic timing and synchronization controls are not needed.
    - Only fewer bits are required for signaling and control.
- *Simple hardware*
    - It does not require adaptive equalization and slot timing adjustment control.
- Higher base station cost
    - The requirement of individual Tx and Rx for each channelaugments the BS cost.
- Requires a duplexer in the mobile unit
    - Duplexer is essential for simulta
    - The cost of a duplexer is 10% of the total cost of a mobile unit
- Perceptible degradation of link quality during handoffs

- Here, the channel time is divided into slots which are arranged into frames.
- Each active user is allocated a unique slot within a frame, in order to support several channels per carrier.
- The entire channel bandwidth is used during each slot.



- Thus, in contrast to FDMA, the transmission inTDMA is discontinuous.
- Users transmit in bursts which are confined toslots specifically assigned to them.
- A set of time slots are assembled into a frame.

- Each slot has
  - ✓ Preamble or frame sync
  - ✓ Word sync
  - ✓ Control and supervisory bits
  - ✓ User data
- The number of slots per frame depends on:
  - ✓ RF bandwidth
  - ✓ Modulation format
  - ✓ Transmission rate



- In TDMA, the message to be transmitted is split into time bursts of length equal to the time slot.
- At the receiver, these burst are collected to assemble the message.
- The use of non-overlapping frequencies in FDMA and time slots in TDMA effectively create channels that are orthogonal in one of the dimension of the time-frequency space.

- TDMA base stations are relatively smaller in physical dimensions and cheaper.
- Duplexers are not needed in TDMA since the time between the assigned slots is sufficient for switch over from one frequency to another.
- TDMA handles inter-channel interference withease.

- The discontinuous mode of transmission and reception in TDMA requires sizable number of overhead bits.
- Inclusion of guard time between the slots reduces the usable channel time as synchronization, control bit overhead and slot guard time could use up to 30% of the channel time.

- Complexity related to synchronization and dynamicslot alignment sub-system.
- Equalization to mitigate inter-symbol interference(ISI) resulting from channel delay spread.

- The use of FDMA and TDMA in cellular environment requires substantial real time coordination in order to use system resources efficiently.
- Similarly, slot-frequency assignment and management could become quite complex in TDMA system .
- To achieve very little channel coordination, robustness and high capacity than in FDMA and TDMA, Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiple Access(OFDMA) are multiple access schemes to be employed.

- Asrar U. H. Sheikh (2004), "*Wireless Communication Theory and Techniques*", ISBN: 978-1-4613-4811-5 (Print) 978-1-4419-9152-2(Online). doi: 10.1007/978-1-4419-9152-2