FNI 421- Mobile Computing

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05 - Wireless Networks & JVM Intro

Agenda

- Foundational Part:
  - Communication Duplexing
    - Time Division Duplexing
    - Frequency Division Duplexing
  - Communication multiple Accesses
    - Frequency Division Multiple Access
    - Time Division Multiple Access
    - Code Division Multiple Access.
- Software
  - Java History
  - Compiler Interpreter
  - Java bytecode

Wireless Network

1. Personal Area Network
2. Local Area Network
3. Wide Area Network
4. Global Area Network

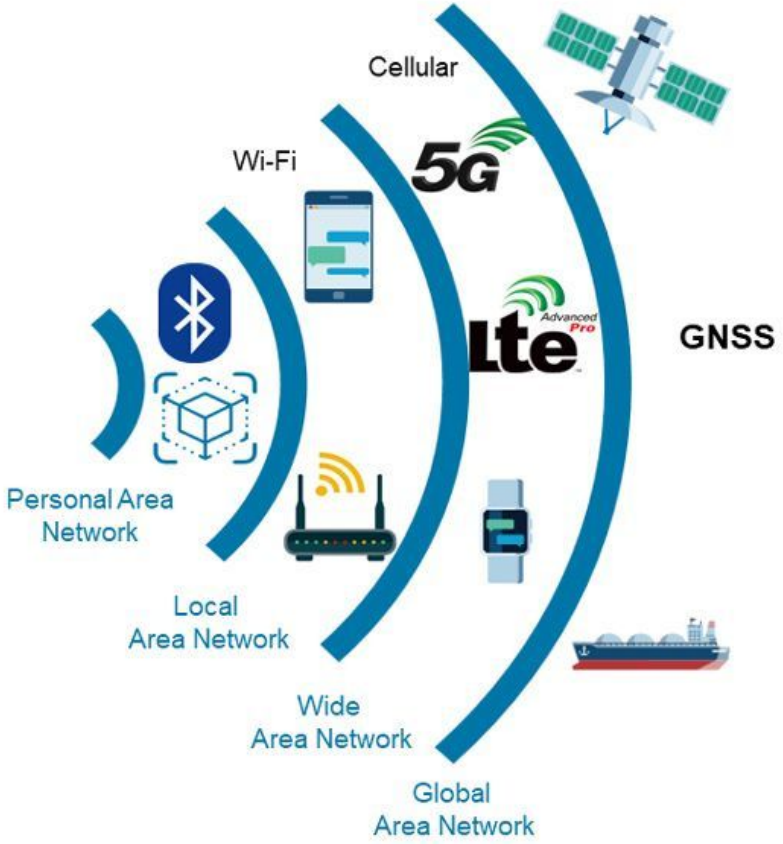


Image from: https://uk.mathworks.com/discovery/wireless-network/_jcr_content/mainParsys/columns/dd83bfca-541d-4181-b0dd-2eedf0ddc4c0/image.adapt.full.medium.jpg/1718283748827.jpg

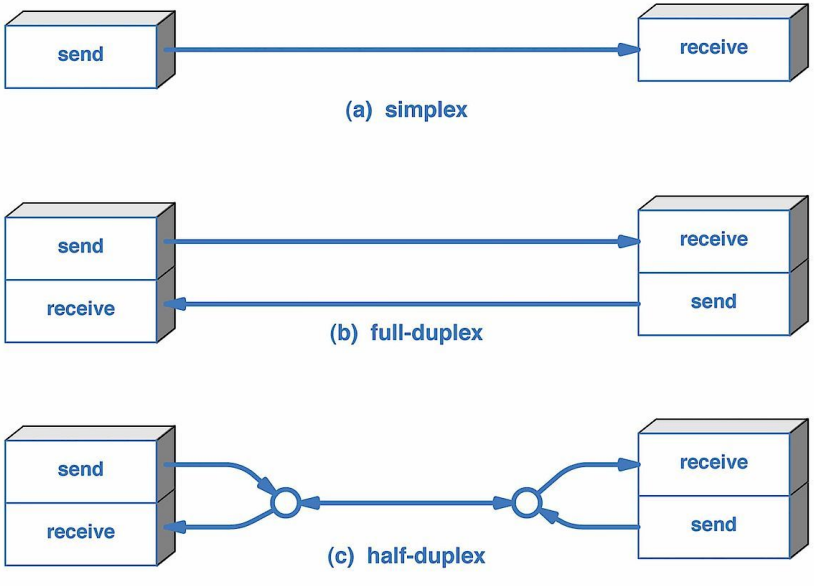
Duplexing and Multiple Access

- **Duplexing** controls how communication is achieved in both directions (uplink and downlink) between two entities, typically a user device and a base station.

- **Multiple Access** manages how multiple users access the same communication medium without interference.

Communication Terms: Duplexing

- A duplex communication system is a point-to-point system composed of two connected parties or devices that can communicate with one another in both directions.
- There are two types of duplex communication systems:
  - full-duplex and
  - half-duplex.



Based on: https://www.networxsecurity.org/members-area/glossary/f/full-duplex.html

Time Division Duplexing

- TDD uses a **single frequency** band for both to transmit and to receive.
- It shares the band by assigning **alternate timeslots** for transmitting and receiving operations.
- Due to the nature of high-speed data, transmissions that are actually competing each other, appear as simultaneous.

Time Division Duplexing - Disadvantage

- The disadvantage is that the successful implementation of TDD requires a timing system.
- The precise timing to both the transmitter and the receiver is needed to ensure that the time intervals do not overlap or interfere with another.

Frequency Division Duplexing

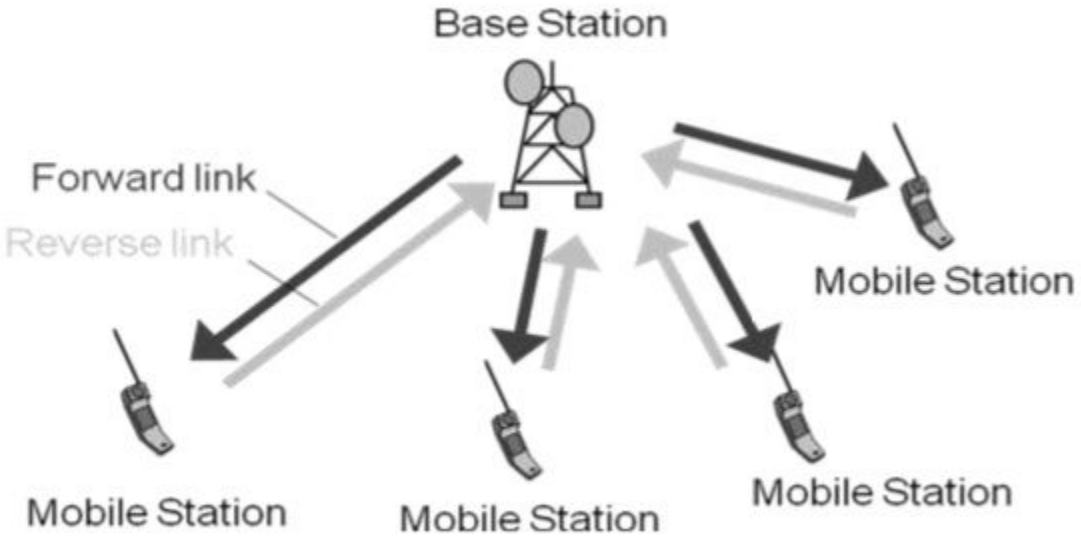
- Is a duplex method whereby the **Uplink** and the **Downlink** transmissions use two separate frequency bands
- Moreover, the uplink and downlink channels need to be separated by **guard bands** to prevent interference between the two channels.
- Guard bands are small frequency ranges that act as buffers between uplink and downlink bands to maintain clear, interference-free communication.

Frequency Division Duplexing - Disadvantages

- FDD uses a lot of frequency spectrum, generally twice of the required TDD spectrum.
- No channel reciprocity: the property in wireless communication where the characteristics of the UL and DL channels between two nodes are symmetric or equivalent.
- there must be adequate spectrum separation between transmission and reception of the channels. Given the scarcity and cost of the spectrum, they are real disadvantages.

Communication Terms: Multiplexing

Allows multiple signals (from different users or data streams) to share the same communication channel.



Based on: https://www.tutorialspoint.com/cdma/images/multiple_access_methods.jpg

Wireless Base Stations (BS)

Wireless Base Stations (BS)

- A Wireless Base Station is a key component of a wireless network that serves as an access point for connecting devices wirelessly.
- It is typically the first device installed in the network and helps transmit data between devices within its range.

Cellular Network Architecture

- **Mobile station (MS)** - Device used to communicate over the cellular network.
- **Base station tranceiver (BST)** - Transmitter/ receiver used to transmit/ receive signals over the radio interface section of the network.
- **Base station controller (BSC)** - Controls communication between a group of BST's and a single MSC.
- **Mobile switching centre (MSC)** - The heart of the network, sets up and maintains calls made over the network.
- **Public switched telephone network (PSTN)** - The land based section of the network.

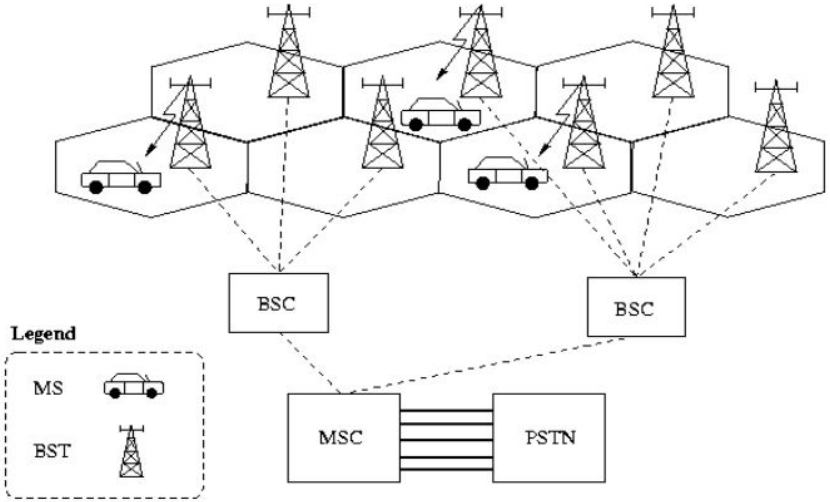
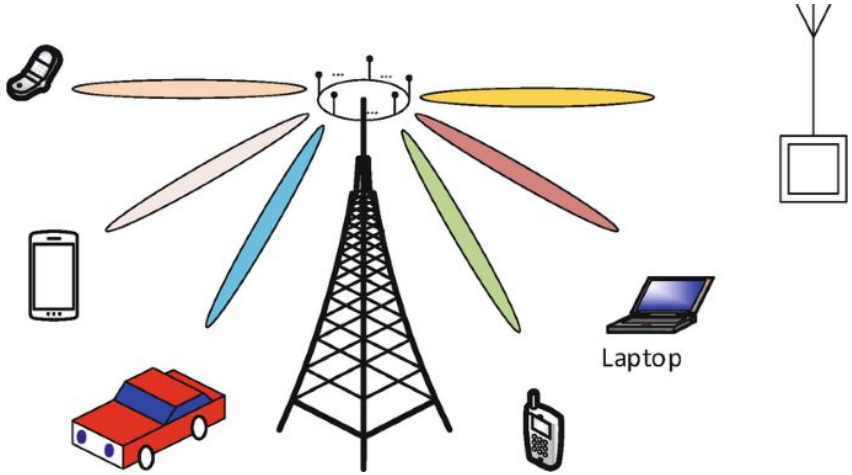


Image from: http://www.hasanbalik.com/LectureNotes/NetworkProtocols/Assignments/CellularNetworkPresentation%20Emine%20Dumlu.pdf

Need For Multiple Access

- It is desirable to allow the subscriber to send information simultaneously from the mobile station to the base station while receiving information from the base station to the mobile station
- Increase the capacity of the channel, i.e., to handle as many calls as possible in a given bandwidth with a sufficient level of quality of service.



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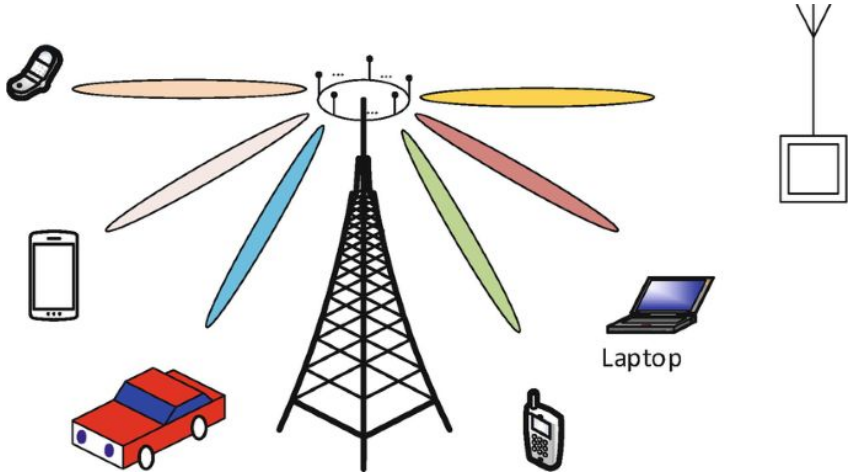
Multiple Access Types

- There are several different ways to allow access to the channel:
  - Frequency division multiple-access (FDMA)
  - Time division multiple-access (TDMA)
  - Code division multiple-access (CDMA)



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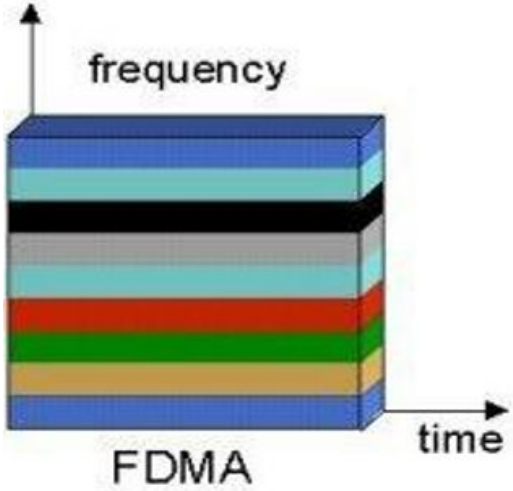
1. Frequency division multiple-access (FDMA)

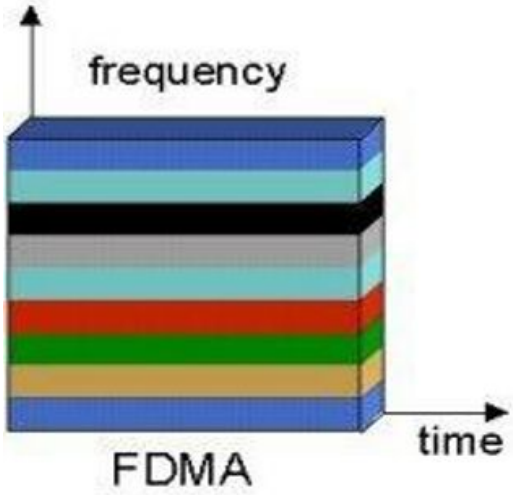
- With FDMA, the transmitting and receiving frequencies used by different users in each cell are different from each other.
- Each cellular call was assigned a pair of frequencies (one for base to mobile, the other for mobile to base) to provide full-duplex operation.
- The original systems had 666 channel pairs, 333 each for the CLEC "A" system and ILEC "B" system.
- The number of channels was expanded to 416 pairs per carrier, but ultimately the number of RF channels limits the number of calls that a cell site could handle.



Based on:https://i0.wp.com/codes.pratikkataria.com/wp-content/uploads/2016/10/fdma-tdma-cdma.png?w=962&ssl=1

1. Frequency division multiple-access (FDMA)

- FDMA can be used with both analog and digital signal but it generally used with analog signal.
- Guard bands lead to a waste of capacity.
- FDMA requires high-performing filters in the radio hardware. Why?



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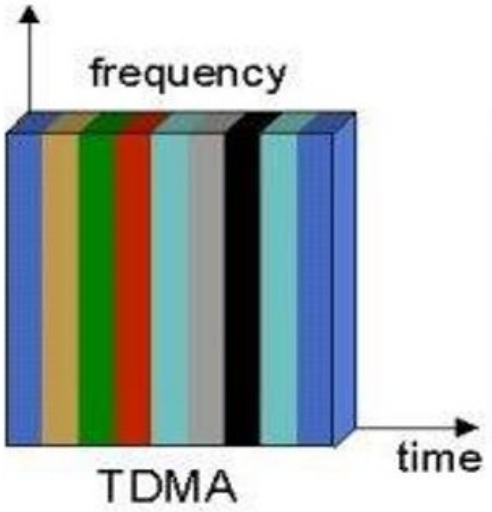
2. Time division multiple-access (TDMA)

- Allows several users to share the same frequency channel by dividing the signal into different time slots.
- The users transmit in rapid succession, one after the other, each using its own time slot.
- This allows multiple stations to share the same transmission medium (e.g. radio frequency channel) while using only a part of its channel capacity.
- TDMA is used in the digital 2G (GSM)



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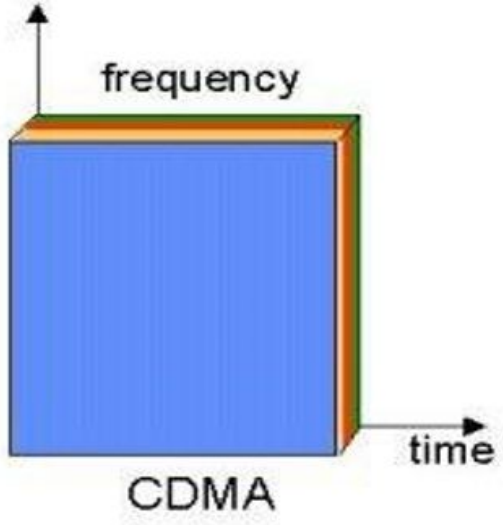
3. Code division multiple-access (CDMA)

- CDMA optimizes the use of available bandwidth as it transmits over the entire frequency range and does not limit the user's frequency range.
- Popularized by 3G, and Qualcomm



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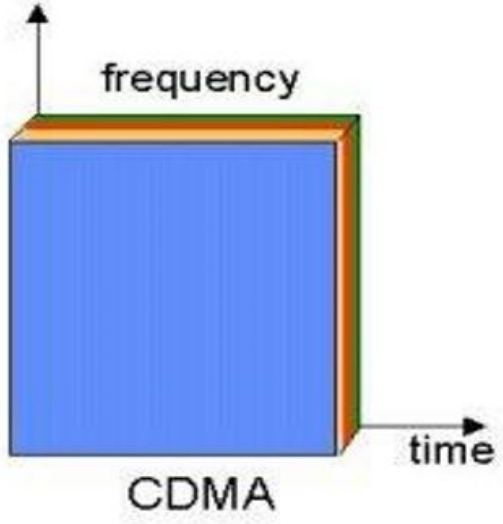
How does the CDMA Work?

- In CDMA, every channel uses the full available spectrum.
- Individual conversations are encoded with a pseudo-random digital sequence and then transmitted using a wide frequency range.
- CDMA consistently provides better capacity for voice and data communications, allowing more subscribers to connect at any given time.



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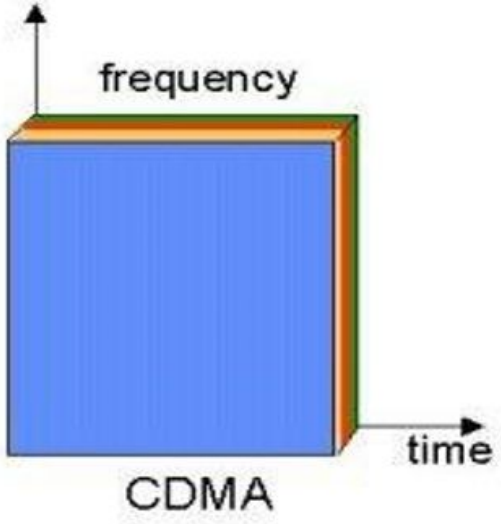
How does the CDMA Work?

- Here, a signal is generated which extends over a wide bandwidth.
- Using a group of codes, which are orthogonal to each other, it is possible to select a signal with a given code in the presence of many other signals with different orthogonal codes.



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Spreading Code

- A spreading code is used to map each data bit in the original signal to multiple bits in the transmitted signal.
- The pseudorandom code (spreading code) spreads the input data across a wider frequency range compared with the input frequency.
- Example:
    - Data: 01
    - Code: 0101
    - Spread x–or message : 0101 1010

Based on:https://i0.wp.com/codes.pratikkataria.com/wp-content/uploads/2016/10/fdma-tdma-cdma.png?w=962&ssl=1

Walsh Code

- Walsh codes are a specific type of spreading code that uses **orthogonal sequences**.
- These sequences have special mathematical properties, ensuring that they have **zero cross-correlation** with each other.
- Signals encoded with different Walsh codes do not interfere, making it easier to differentiate multiple users' signals in a shared frequency.

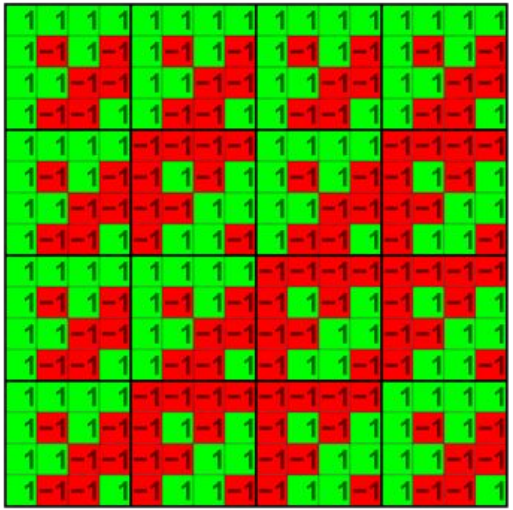

Image from: https://upload.wikimedia.org/wikipedia/commons/3/34/Walsh_16_%2A_Gould%27s-Morse.svg

Walsh Code

- In mathematics, a Walsh matrix is a specific square matrix of dimensions 2n, where n is some particular natural number.
- The entries of the matrix are either +1 or −1 and its rows as well as columns are orthogonal
- Walsh Codes are most commonly used in the orthogonal codes of CDMA applications.
- These codes correspond to lines of a special square matrix called the Hadamard matrix.
- For a set of Walsh codes of length N, it consists of n lines to form a square matrix of n × n Walsh code.

$$H_1 = [1]; \qquad H_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix};$$

$$H_4 = H_2 \otimes H_2 = \begin{bmatrix} H_2 & H_2 \\ H_2 & -H_2 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix}$$

Image from: https://upload.wikimedia.org/wikipedia/commons/3/34/Walsh_16_%2A_Gould%27s-Morse.svg

Walsh Code - Zero Cross Correlation Test

- Is a check between two paris of codes to check if they have zero cross correlation.
- Given two codes W_1 and W_2, the Zero Cross Correlation Test is defined as:
  - Passed if : W_2 * W_2 = 0
  - Failed if : W_2 * W_2 != 0

Image from: https://upload.wikimedia.org/wikipedia/commons/3/34/Walsh_16_%2A_Gould%27s-Morse.svg

Walsh Code - Zero Cross Correlation Test

Check the zero cross correlation for

1. W_1=[1,1,1,1]
2. W_2=[1,-1,1,-1]

Check:

W_1 * W_2 = 1-1+1-1 = 0

=> zero cross correlation test passed

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Walsh Code - Zero Cross Correlation Test

Check the zero cross correlation for

1. W_1=[1,1,1,1]
2. W_2=[1,-1,1,-1]

Check:

W_1 * W_2 = 1-1+1-1 = 0

=> zero cross correlation test passed

Check the zero cross correlation for

1. W_1=[1,1,1,1]
2. W_2=[2,-1,2,-1]

Check:

W_1 * W_2 = 2-1+2-1 = 2

=> zero cross correlation test failed

Image from: https://upload.wikimedia.org/wikipedia/commons/3/34/Walsh_16_%2A_Gould%27s-Morse.svg

CDMA Example - Sender Side:

Data to be sent	01							
Walsh Code	0	1	0	1				
Spread message for first bit (0 xor walsh code)	0	1	0	1				
Spread message for second bit (1 xor walsh code)	1	0	1	0				
Spread message	0	1	0	1	1	0	1	0
Spread message with voltages (bit 0 = +1, bit 1= -1)	+1	-1	+1	-1	-1	+1	-1	+1

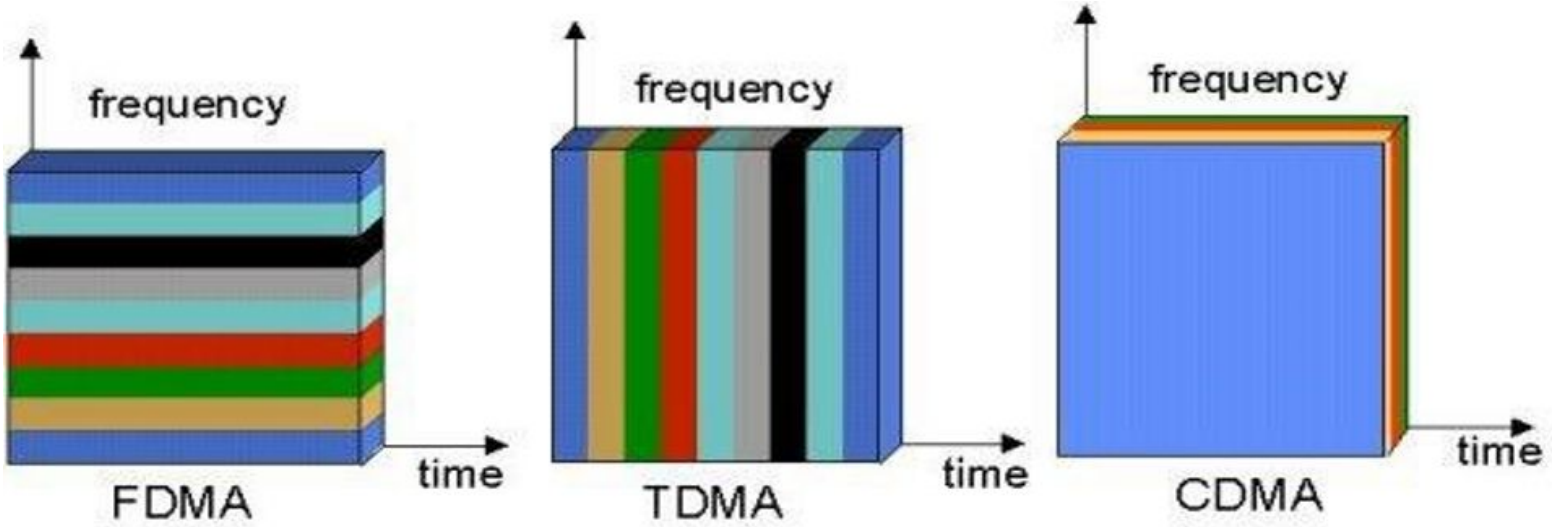
Image from: https://upload.wikimedia.org/wikipedia/commons/3/34/Walsh_16_%2A_Gould%27s-Morse.svg

CDMA Example - Receiver Side:

Data Received	+1	-1	+1	-1	-1	+1	-1	+1
Walsh Code (repeated)	0	1	0	1	0	1	0	1
Walsh Code (repeated as voltages, bit 0 = +1, bit 1= -1)	+1	-1	+1	-1	+1	-1	+1	-1
Multiply data received by walsh code as voltages	+1	+1	+1	+1	-1	-1	-1	-1
Split and add each 4-bits to start recovering the original message	4				-4			
Divide each by the number of bits in the Walsh code	4/4=1				-4/4=-1			
Recover the original message in bits removing voltages	0				1			

Image from: https://upload.wikimedia.org/wikipedia/commons/3/34/Walsh_16_%2A_Gould%27s-Morse.svg

Multiple-Access



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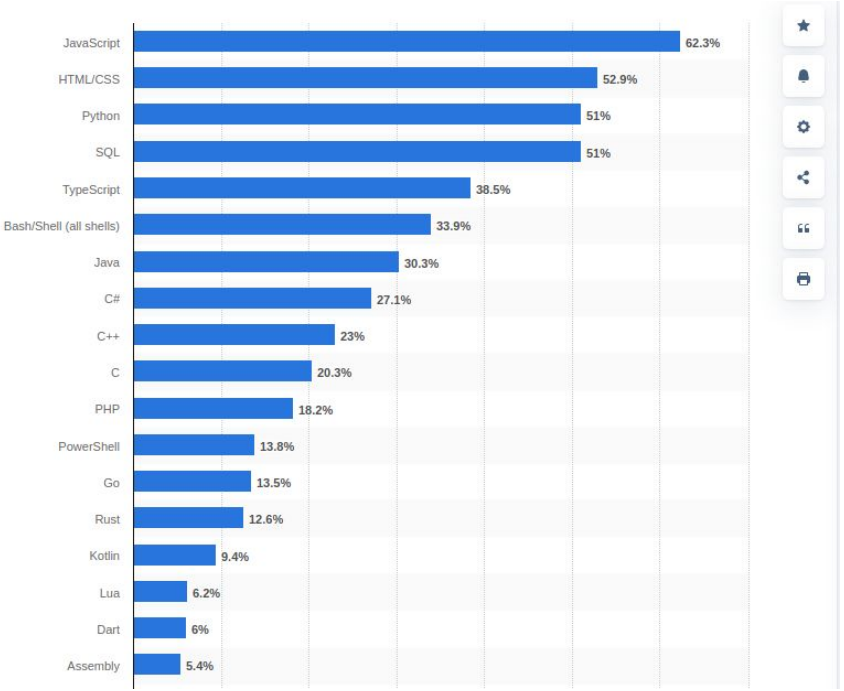
Why Java?

Who initiated Java?

- James Gosling (born 19 May 1955) is a Canadian computer scientist, best known as the founder and lead designer behind the Java programming language.
- Java was originally developed by James Gosling at Sun Microsystems.
- It was released in May 1995 as a core component of Sun's Java platform.
- Sun acquisition by Oracle.
- OpenJDK is a community open-source implementation of the Java platform

Why Java?

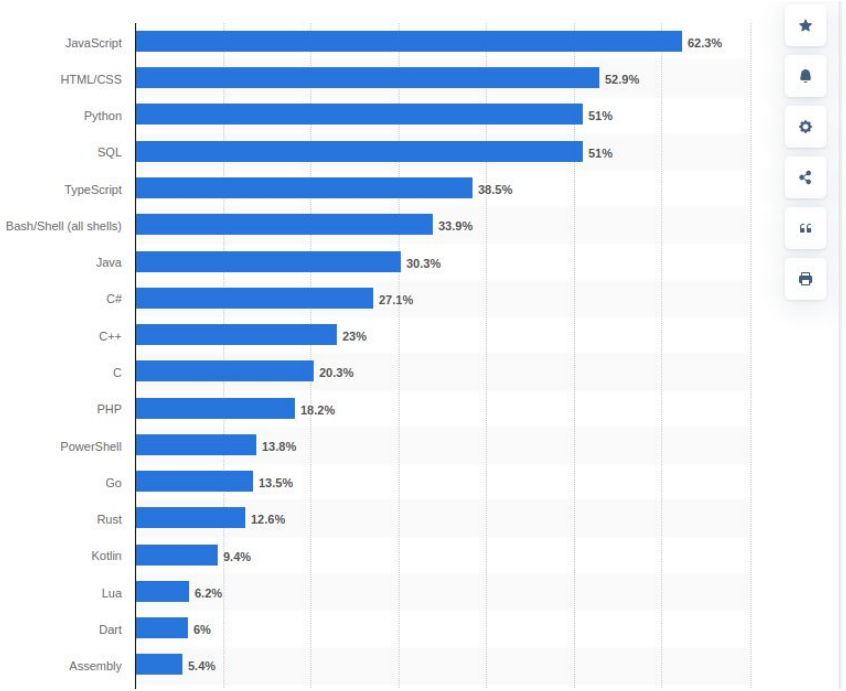
- **Versatility:** Java is used in various applications, from web and mobile development to enterprise solutions and cloud computing.
- **Platform Independence:** Java's "write once, run anywhere" capability allows you to run applications on any device that has a Java Virtual Machine (JVM).
- **Strong Community Support:** Java has a large and active community, providing a wealth of resources, libraries, frameworks, and tools to aid development.
- **Object-Oriented Programming (OOP):** Learning Java helps you understand OOP principles, which are fundamental to many programming languages and software design.
- **Robustness and Security:** Java offers strong memory management and security features, making it a reliable choice for building secure applications.
- **Enterprise-Level Applications:** Many large organizations use Java for their backend systems, making it valuable for working in enterprise environments.
- **In nutshell:** learning Java allows you to work on more than just mobile application.



https://www.statista.com/statistics/793628/worldwide-developer-survey-most-used-languages/

The Java Language

- Java is a high-level, class-based, object-oriented programming language.
- Intended to let programmers write once, run anywhere
- Java applications are typically compiled to bytecode that can run on any Java virtual machine (JVM) regardless of the underlying computer architecture.
- The syntax of Java is similar to C and C++, but has fewer low-level facilities than either of them.
- The Java runtime provides dynamic capabilities (such as reflection and runtime code modification) that are typically not available in traditional compiled languages.



Compiler

- A compiler translates the entire source code of a program into machine code (or bytecode) before execution.
- The output is an executable file that can be run independently of the original source code.
- Generally faster
- C, C++, and Rust are typically compiled languages.

Interpreter

- An interpreter translates source code line-by-line or statement-by-statement at runtime, executing it immediately.
- There is no separate executable file; the source code must be present during execution.
- Generally slower at runtime since it translates code on-the-fly.
- Python, Ruby, and JavaScript are typically interpreted languages.

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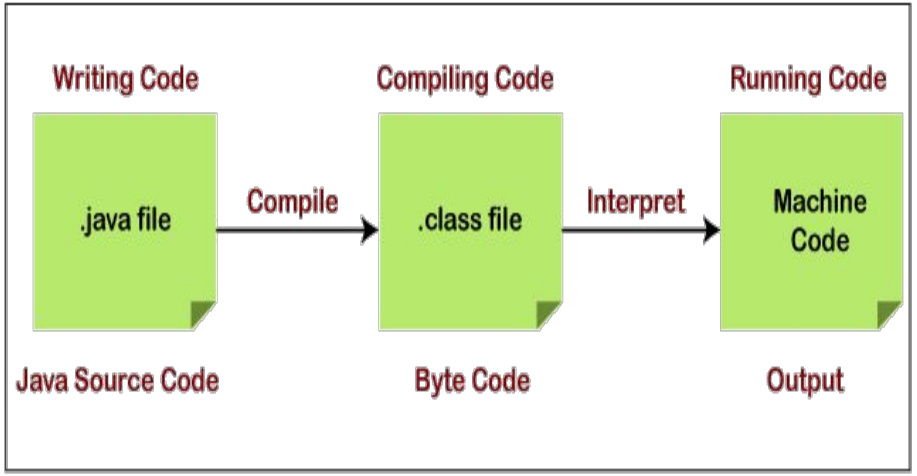
What about Java? Which category does it belong to?

The Java Language

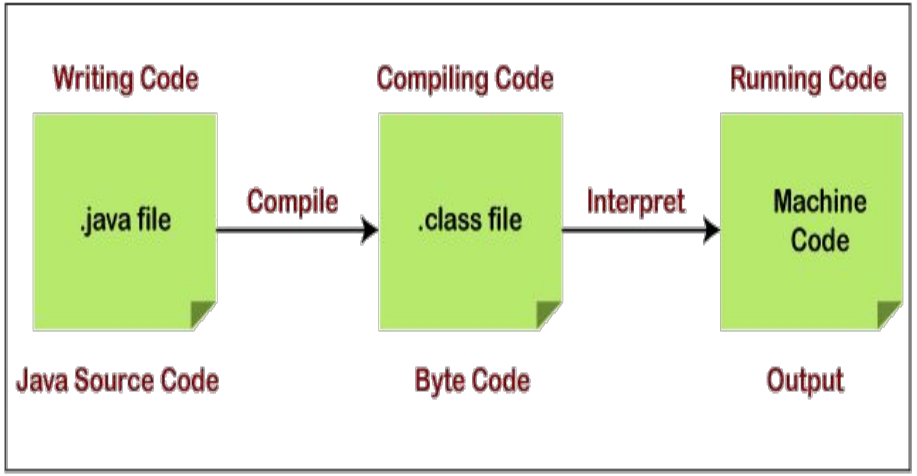
- Java compiles to an intermediate representation called Java bytecode. This is instead of directly to architecture-specific machine code.
- Java bytecode instructions are analogous to machine code, but they are intended to be executed by a virtual machine (VM) written specifically for the host hardware.
- End-users commonly use a Java Runtime Environment (JRE) installed on their device for standalone Java applications or a web browser for Java applets.




```
javap -c HelloWorld.class
```

The Java Language

- The use of universal bytecode makes porting simple. However, the overhead of interpreting bytecode into machine instructions made interpreted programs almost always run more slowly than native executables.
- Just-in-time (JIT) compilers compile byte-codes to machine code during runtime, allowing repulling of the machine code instead of the recompilation.
- Uses automatic garbage collection for memory management.
- Standard libraries provide a generic way to access host-specific features such as graphics, threading, and networking.



How JVM Works – JVM Architecture

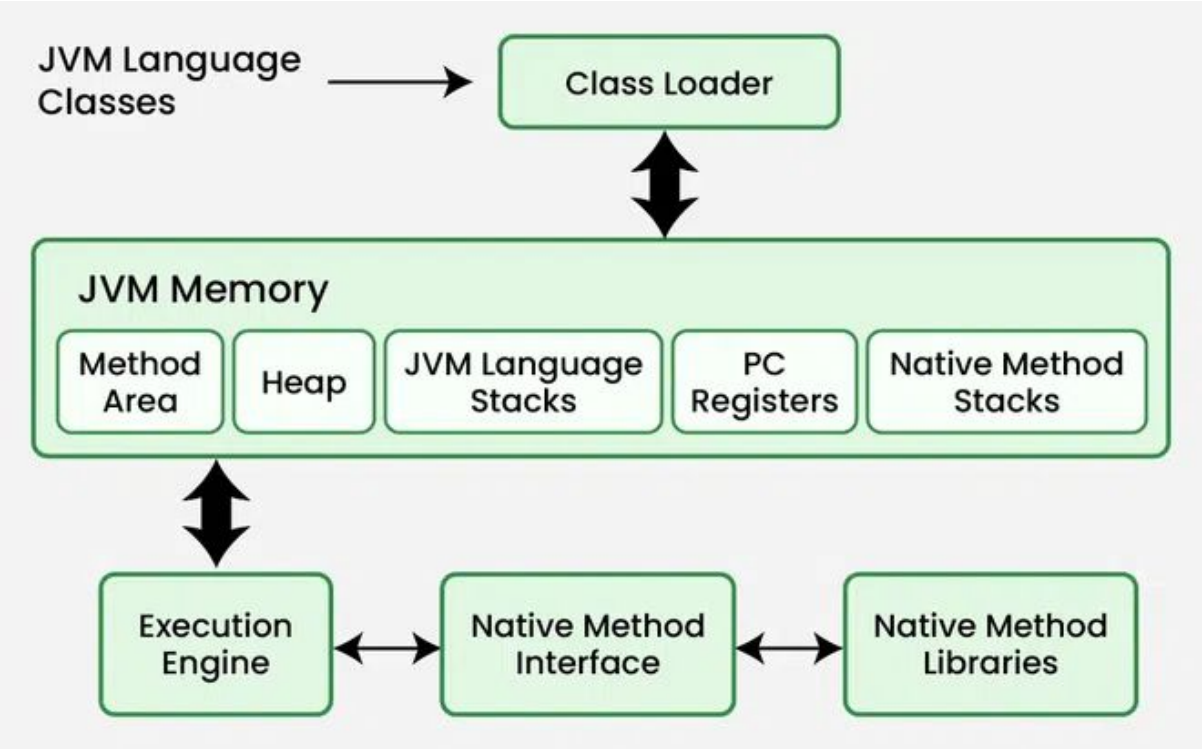


Image fromhttps://www.geeksforgeeks.org/jvm-works-jvm-architecture/

Readings

- Read about CDMA on WikiPedia.
- Read CDMA complete guide on tutorialsPoint.
- Read more about the Java JVM in this GeeksforGeeks article.

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