REPORT -4

WIRELESS COMMUNICATIONS

Prof. Dr. Said E. El-Khamy
Communication & Electronics

Asmaa Gamal Abdel-Halem Mabrouk Nagy
أسماء جمال عبد الحليم مبروك ناجي
15010473

CDM/CDMA code division spread spectrum techniques - IS 95 - Rake Receivers- Soft handover- Frequency Hopping & its Applications In Bluetooth

Table of contents:

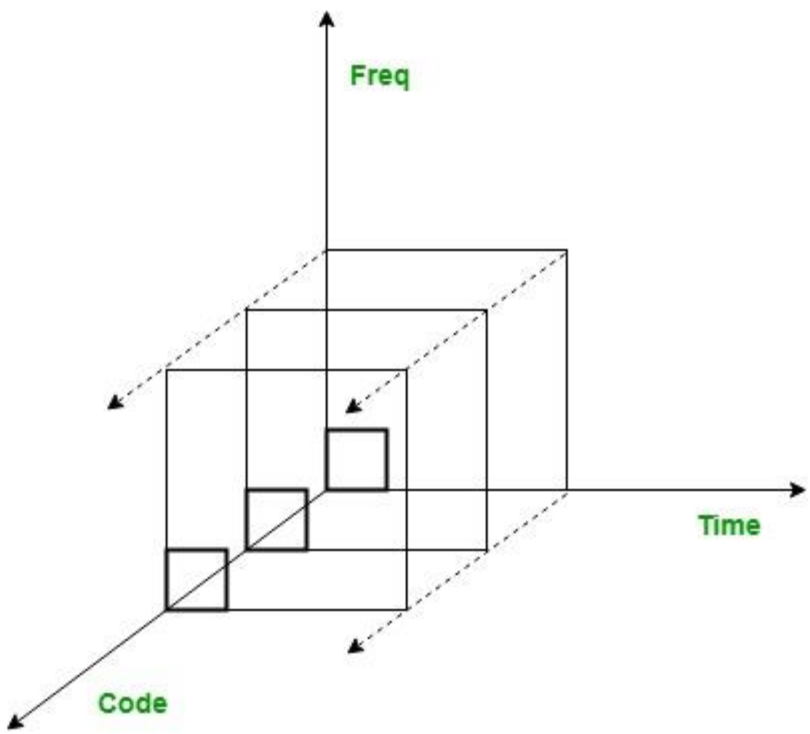
IS-95

IS-95, also known as cdmaOne, is a digital cellular technology that utilizes Code Division Multiple Access (CDMA) for communication. It was developed primarily for the North American market and was one of the earliest generations of CDMA-based mobile communication systems. IS-95 provided significant improvements over analog cellular systems in terms of capacity and call quality. It served as the foundation for subsequent CDMA standards and technologies.

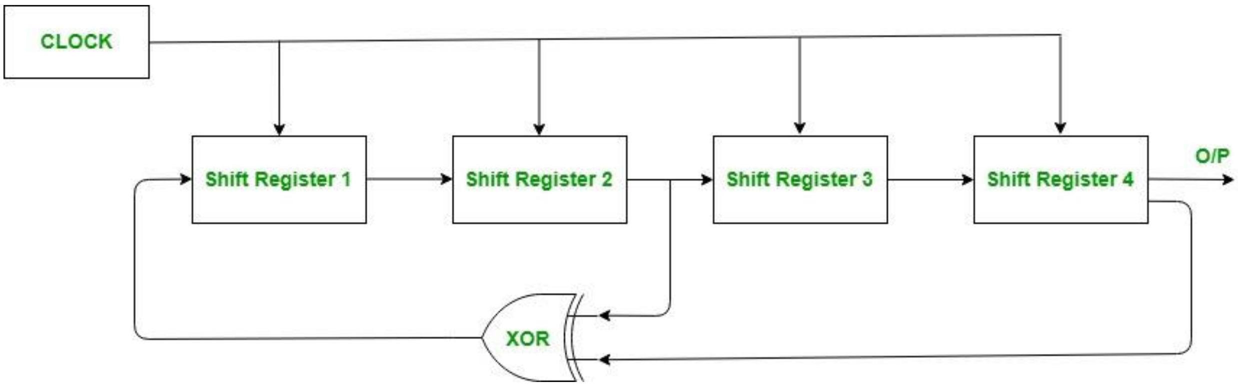
It is an 2G cellular system based on DS-CDMA. To understand IS-95 we need to understand DS and CDMA separately.

- DSSS is Direct Sequence Spread Spectrum Technique which is a spread spectrum technique in which the data to be transmitted is encoded using spreading code and received and then decoded using the same code. It is used to avoid interference, spying and jamming. The spreading code used is known to transmitter and receiver only.

- CDMA stands for Code Division Multiple Access. It uses the same bandwidth for all the users. However, each user is assigned a separate code which differentiates the from each other.



Narrow bandwidth signals are multiplied with a very large bandwidth signals called Pseudo Noise Code Sequence (PN code). Each user has its own PN code which is orthogonal to each other. Auto-correlation is maximum and cross-correlation is zero of these PN codes. They repeats itself after a very large time period and hence, appears to be random. PN Sequence is generated by Linear Feedback Shift Register.



Power Control in IS-95:
It solves the Near-far problem in which transmitters at different distances transmits signal of same power then the power of the signal of Transmitter (nearer to the base station) will be greater than that of Transmitter (farther to the base station). So in power control technique transmitter nearer to the base station transmits less power signal that of the transmitter farther.

It is of two types:

- Open loop power control:
  Transmitter senses the power of the received signal at the base station and then adjusts its transmitting power accordingly in subsequent transmissions.
- Closed loop power control:
  Base station sends the received signal power information to the transmitter and tells to increment or decrement the transmission power accordingly in subsequent transmissions.

Advantages of IS-95 in CDMA Technology

IS-95 provides increased network capacity and efficiency, enhanced call quality and coverage, as well as reduced interference and noise.

Increased Capacity and Efficiency

- IS-95 allows simultaneous communications between multiple users
- Utilizes frequency reuse techniques to reduce interference and noise levels
- More users can be accommodated without degrading quality of service
- Efficient use of bandwidth maximizes available resources
- Reduces costs for mobile operators by improving spectrum efficiency

Enhanced Call Quality and Coverage

- Improved voice clarity and audio quality
- Seamless handovers between cells for reliable communication
- Paved the way for the development of 3G and 4G technologies
- Higher capacity for calls without interference
- Maintains connectivity for mobile devices moving between cell sites

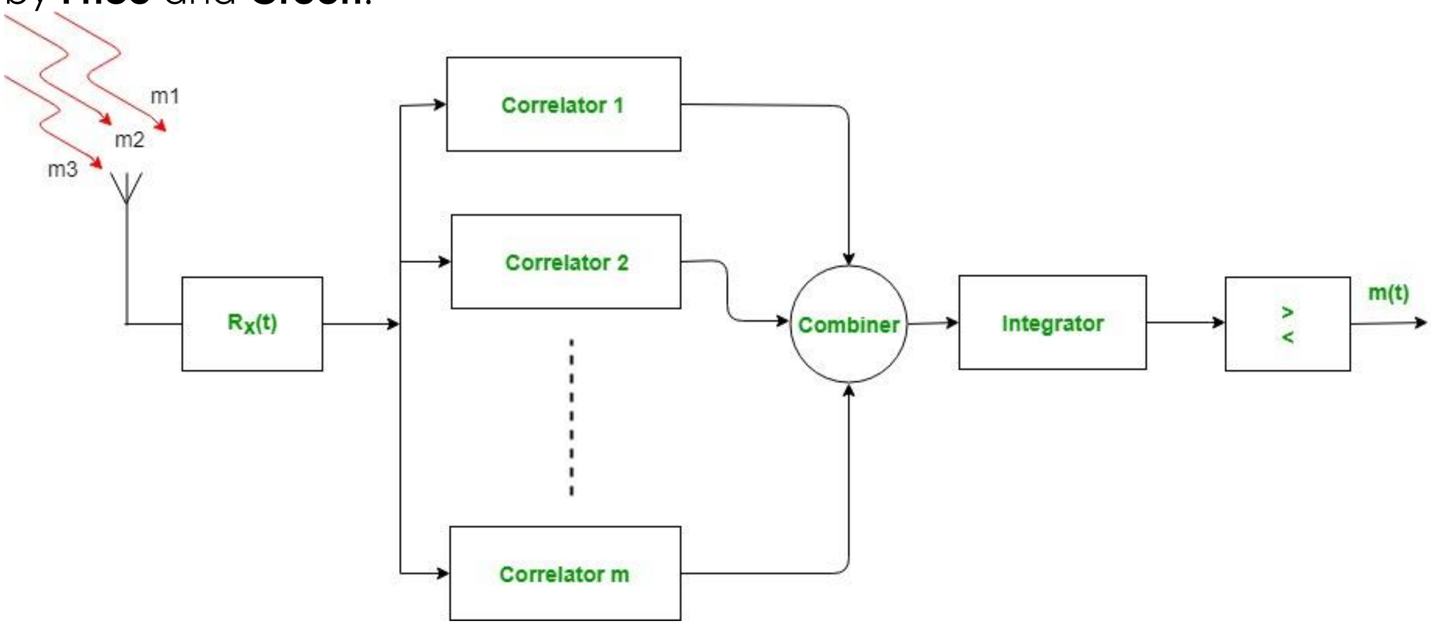
Reduced Interference and Noise

- Uses spread spectrum technology to minimize interference
- Frequency reuse patterns reduce co-channel interference
- Better call quality and coverage over larger geographic areas
- Fewer dropped calls and clearer communication for users
- More reliable roaming capabilities due to reduced signal degradation

Rake Receiver

A rake receiver is a radio receiver designed to counter the effects of multipath fading. It does this by using several "sub-receivers" called fingers, that is, several correlators each assigned to a different multipath component. Each finger independently decodes a single multipath component; at a later stage the contribution of all fingers are combined in order to make the most use of the different transmission characteristics of each transmission path. This could very well result in higher signal-to-noise ratio (or Eb/N0) in a multipath environment than in a "clean" environment.

The dictionary meaning of rake is *to gather or collect together something* and actually is a garden tool to collect leaves. But in the terms of computer network, it is for the purpose of collecting signals from multiple paths arriving at the receiver end and used specially in CDMA cellular systems. A Rake Receiver is a radio receiver which is designed for the purpose to counter the effects of multipath fading. Due to reflections from multiple obstacles in the environment, the radio channel can consist of multiple copies of the transmitted signal having different amplitude, phases or delays. A rake receiver can resolve this issue and combine them. For this purpose, several sub-receivers are used which are known as “fingers”. The idea of a basic rake receiver was first proposed by **Price** and **Green**.



When the transmitter transmits the signal then it travels through the environment which consists of various obstacles and the transmitted signal is reflected by them and is received by the rake receiver from multiple paths. Rake receiver then feeds them to different fingers (correlators). The delays in each received signal are compensated and are feeded to the Combiner, Integrator and Comparator which combines them suitably with different appropriate time delays.

Working of Rake Receiver:

1. The received signal from multiple paths arrives at the antenna with different delays and phases.
2. The signal is first passed through a bank of matched filters, each of which corresponds to a specific path.
3. The output of each matched filter is sampled at the symbol rate and the resulting samples are combined.
4. The combining process is done using a technique called maximum ratio combining (MRC) which gives more weight to the signals that have higher signal-to-noise ratio (SNR).
5. The combined signal is then demodulated to obtain the transmitted symbols.
6. The rake receiver also performs channel estimation by estimating the complex gains of each path using a technique called pilot symbols.
7. The channel estimates are used to adjust the weights in the combining process to ensure optimal performance.
8. The rake receiver also uses a technique called diversity combining to reduce the effect of fading by combining the signals from multiple antennas.
9. The combined signal from each antenna is then passed through the matched filter and combined using maximum ratio combining.
10. The rake receiver is able to recover the transmitted signal even in the presence of severe multipath fading and interference.

Some key applications of Rake receiver are:

- **CDMA Systems:** Rake receivers are extensively used in CDMA systems, where they are used to combat the effects of multipath fading.
- **Wireless Networks:** Rake receivers are also used in wireless networks to improve the performance of the system, especially in environments where the signal is weak.
- **Satellite Communications:** In satellite communication systems, Rake receivers are used to detect and extract weak signals that have traveled long distances.

- **Mobile Communications:** Rake receivers are used in mobile communication systems to improve the quality of the received signal by minimizing the effects of multipath fading.
- **High-Speed Data Transmission:** Rake receivers are used in high-speed data transmission systems to reduce errors caused by the transmission of signals over long distances.

Some key advantages of rake receiver are:

- **Multipath mitigation:** The rake receiver mitigates the effect of multipath propagation by combining multiple replicas of the same signal, which have been transmitted over different paths.
- **Diversity gain:** By combining multiple replicas of the same signal, the rake receiver provides diversity gain, which helps to improve the signal-to-noise ratio (SNR) and reduce the bit error rate (BER) of the received signal.
- **Interference rejection:** The rake receiver can also be used to reject interference from other signals that are transmitted over the same frequency band.
- **Simple implementation:** The rake receiver is a simple and effective technique that can be implemented using digital signal processing (DSP) algorithms.
- **Compatibility:** The rake receiver is compatible with different modulation schemes and can be used in various wireless communication systems, such as code division multiple access (CDMA), time division multiple access (TDMA), and frequency division multiple access (FDMA).
- **Improvement in system capacity:** The use of a rake receiver in a wireless communication system can increase the system capacity by allowing the use of more frequency bands or by increasing the number of users that can be supported.

Some key disadvantages of rake receiver are:

- **Complex implementation:** The Rake receiver is a complex receiver with a large number of matched filters, which makes it difficult to implement.
- **High power consumption:** The Rake receiver requires a lot of power to operate, which can be a problem in battery-powered devices.
- **Limited performance in deep fades:** The Rake receiver is not very effective in deep fades, where the signal is severely attenuated. In such cases, other techniques such as diversity combining may be more effective.
- **Sensitivity to multipath delay spread:** The Rake receiver is designed to work in the presence of multipath, but it is sensitive to the delay spread of the

channel. In channels with large delay spreads, the performance of the Rake receiver may degrade.

- **Limited applicability to narrowband systems:** The Rake receiver is designed to work with wideband systems that have significant multipath propagation. In narrowband systems with little or no multipath, the Rake receiver may not be necessary or effective.

The Rake receiver is an important solution to the problem of multipath fading in wireless communication. It is designed to improve the signal quality and reduce the effects of fading by using multiple copies of the transmitted signal that arrive at the receiver at different times. Although the Rake receiver is more complex, more power-consuming, and more expensive than other types of receivers, it provides better coverage and improved data rates, making it an attractive solution for high-speed wireless communication.

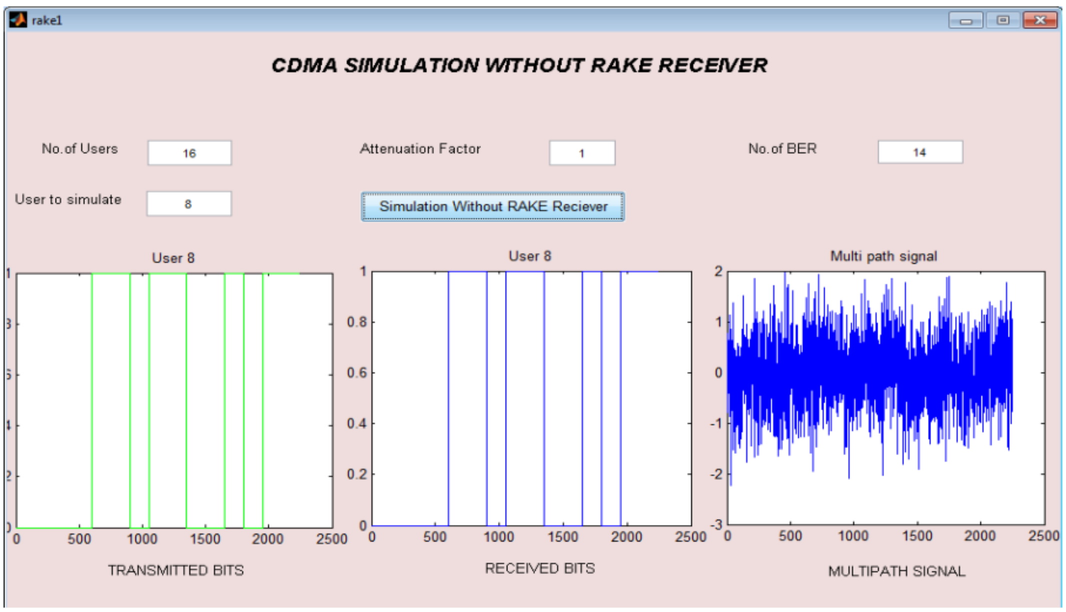


Fig. 5: Simulation without Rake when attenuation factor is 1

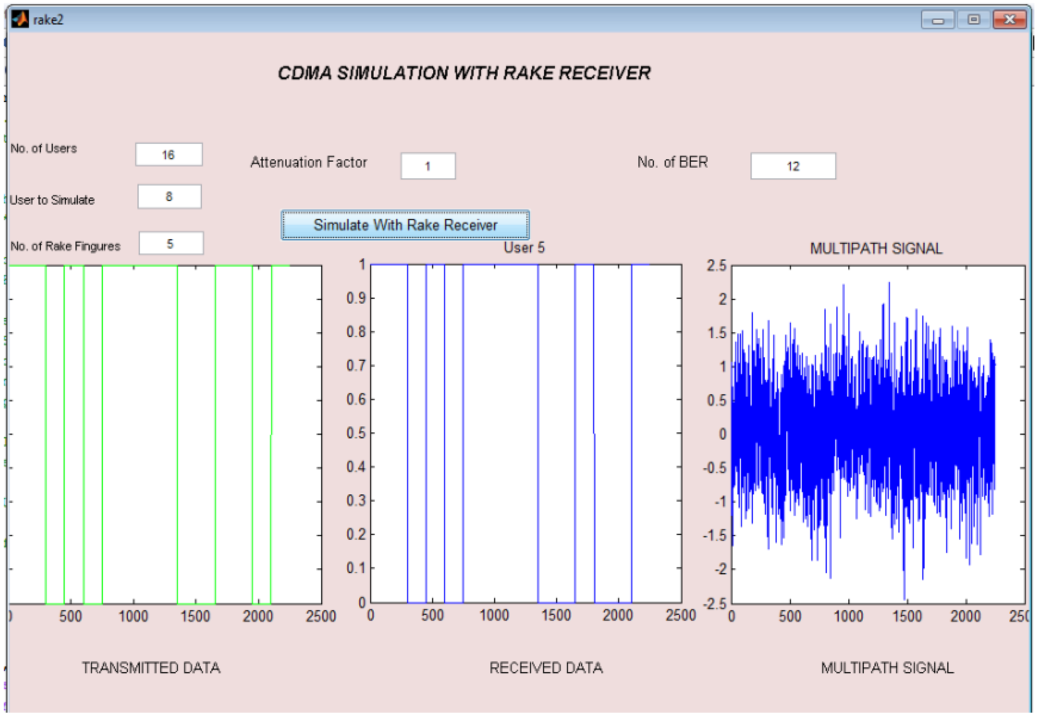


Fig. 6: Simulation with Rake when attenuation factor is 1

Result Comparison: (with Rake)

Reference Paper Result: (for 4 user)

Attenuation Factor	Bit Error Rate
1.0	0

Project Result: (for 16 user)

Attenuation Factor	Bit Error Rate
1.0	12
2.0	6
4.0	1
6.0	1
8.0	1
10.0	0

Table 1: Actual Result Comparison with Rake Receiver

Result Comparison: (without Rake)

Reference Paper Result: (for 4 user)

Attenuation Factor	Bit Error Rate
1.0	0

Project Result: (for 16 user)

Attenuation Factor	Bit Error Rate
1.0	14
2.0	7
4.0	5
6.0	2
8.0	1
10.0	1

Table 2: Actual Result Comparison without Rake Receiver

Rake receiver is used for CDMA to decrease a bit error rate due to its multipath interferences.It can simulate a CDMA encoding and decoding process, the data is assumed to be traveled through different path, the effect of different path and CDMA is considered to generate the multipath effect the data is passing through the different path and assumed at receiver end just before the decoder.The developed simulator can be a very helpful tool to carry out the performance of a Rake Receiver with various attenuation factors. As for example the simulator can be used to find the antenna diversity schemes at the receiver. The simulator is very flexible and one can very easily make the necessary modification to incorporate complex statistical channel model based on measurement and investigate.

Different frequency hopping techniques

There are indeed various frequency hopping techniques employed in different wireless communication systems. While Bluetooth uses a specific frequency hopping scheme defined by its standard, other systems may utilize different approaches tailored to their requirements. Here are a few examples:

- **Bluetooth Frequency Hopping Spread Spectrum (FHSS):** Bluetooth divides the 2.4 GHz ISM band into 79 (or 40 in Bluetooth Low Energy) channels and hops between them at a rate of 1600 hops per second. The hopping sequence is determined by a master device, and all devices in communication synchronize to this sequence.
- **Wi-Fi Direct Sequence Spread Spectrum (DSSS):** Wi-Fi (IEEE 802.11) typically uses Direct Sequence Spread Spectrum (DSSS) or Orthogonal Frequency Division Multiplexing (OFDM) modulation techniques. In DSSS, the signal is spread across a wide bandwidth using a pseudo-random sequence. However, Wi-Fi does not employ frequency hopping; instead, it spreads the signal across the entire bandwidth.
- **Frequency Hopping Spread Spectrum (FHSS) in Military Radios**: Military communication systems often employ FHSS for its resistance to interference and interception. These systems hop over a broader range of frequencies compared to Bluetooth, and the hopping pattern is usually more dynamic and unpredictable.
- **Zigbee Frequency Agility:** Zigbee is a low-power, low-data-rate wireless communication technology used in applications such as home automation and industrial control. Zigbee devices can operate in multiple frequency bands, including 2.4 GHz and 900 MHz, and may employ frequency agility techniques to avoid interference in crowded environments.
- **Adaptive Frequency Hopping (AFH) in Bluetooth:** Bluetooth versions after 1.2 introduced Adaptive Frequency Hopping (AFH) to improve coexistence with other wireless technologies in the 2.4 GHz band. AFH dynamically avoids channels with interference, enhancing the reliability of Bluetooth connections.

These examples illustrate the diversity of frequency hopping techniques used in various wireless communication systems, each tailored to specific requirements such as interference avoidance, spectrum efficiency, or resistance to jamming. Each system's hopping scheme is designed to optimize performance within its intended application and operating environment.

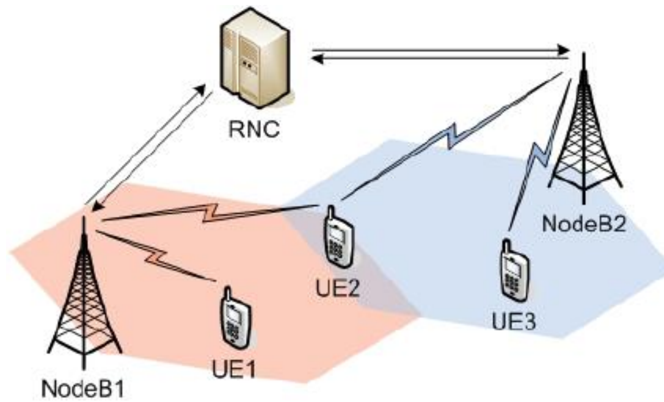
Soft Handover

Soft handover is a feature in cellular telecommunications networks that allows a mobile device to communicate simultaneously with multiple base stations (or cell sites) during a handover process.

Here's how soft handover works:

- **Mobile Station Movement**: When a mobile device (such as a smartphone) moves from the coverage area of one base station to another (usually due to physical movement), a handover process is initiated to maintain the ongoing call or data session.
- **Connection to Multiple Base Stations:** During soft handover, the mobile device establishes connections with both the current serving base station (the one it is leaving) and the target base station (the one it is entering). This means that the mobile device is momentarily in communication with two or more base stations simultaneously.
- **Signal Combining:** The signals received from the multiple base stations are combined at the mobile device's receiver. This combining process helps mitigate issues such as signal fading, interference, and fluctuations in signal strength.
- **Seamless Transition:** Soft handover allows for a seamless transition of the mobile device's connection from the current base station to the target base station without interrupting the ongoing call or data session. This ensures continuity of service and improves the overall user experience.
- **Enhanced Reliability and Coverage:** Soft handover increases the reliability of the cellular network by providing redundancy through connections to multiple base stations. It also improves coverage, particularly in areas where signals from multiple base stations overlap or where signal strength is variable.

Soft handover is a fundamental feature in many cellular technologies, including GSM, UMTS (3G), CDMA2000, and LTE (4G). It plays a crucial role in maintaining the quality and continuity of mobile communications, especially in environments with fast-moving mobile devices or challenging radio conditions.



conditions.

Advantages of Soft Handover:

- Improved Call Quality: Soft handover helps maintain a strong and stable connection by combining signals from multiple base stations. This reduces the likelihood of dropped calls and enhances call quality, particularly in areas with signal variations or interference.
- Enhanced Data Transfer: In addition to voice calls, soft handover also benefits data sessions. By utilizing signals from multiple base stations, it improves data transfer rates and reduces packet loss, leading to smoother and more reliable data connections for tasks like streaming video or browsing the internet.
- Seamless Mobility: Soft handover allows mobile devices to seamlessly transition between different cells without interruption. This is especially beneficial for users who are moving at high speeds, such as passengers in vehicles or users on trains, as it ensures uninterrupted communication during handover events.
- Increased Network Capacity: Soft handover increases network capacity by distributing traffic across multiple base stations. This optimizes resource utilization and reduces congestion in individual cells, leading to better overall network performance and user experience.
- Robustness to Interference and Fading: By combining signals from multiple base stations, soft handover improves resistance to signal fading and interference. This is particularly advantageous in urban environments with dense buildings or in areas with challenging radio propagation conditions.

Implementation Considerations:

- Handover Triggering: Soft handover is typically triggered based on measurements of signal strength and quality. Mobile devices continuously monitor neighboring cells and initiate handover when predefined thresholds are met, ensuring smooth transitions between cells.
- Resource Allocation: Soft handover requires additional resources both in the mobile device and in the network. Network planning and optimization are essential to allocate resources efficiently and minimize overhead while maximizing the benefits of soft handover.
- Compatibility: Soft handover is supported by most modern cellular technologies, including GSM, UMTS, CDMA2000, and LTE. However, interoperability between different network technologies and vendors may require careful configuration and testing to ensure seamless handover operations.
- Impact on Battery Life: Soft handover may have a slight impact on the battery life of mobile devices due to increased processing and communication overhead. However, advancements in power management techniques help mitigate this impact, ensuring optimal battery performance.

Overall, soft handover is a critical feature in cellular networks, providing numerous benefits such as improved call quality, seamless mobility, increased network capacity, and robustness to interference. Its effective implementation requires careful planning, optimization, and coordination between network elements to deliver a reliable and high-quality user experience.

Power Control

Power control is a crucial aspect of wireless communication systems, particularly in cellular networks, where efficient management of transmit power is essential for optimizing system performance, maximizing coverage, and conserving battery life. Here's a comprehensive overview of power control in wireless communication:

1. Purpose of Power Control:

- Coverage Optimization: Adjusting transmit power ensures that signals reach the intended recipients without excessive interference or wastage.
- Interference Mitigation: Controlling transmit power reduces interference to neighboring cells or users operating in the same frequency band.
- Battery Conservation: In mobile devices, power control helps conserve battery life by adjusting transmit power based on the distance to the base station or other communicating devices.
- Spectral Efficiency: Optimizing transmit power improves spectral efficiency by minimizing unnecessary power consumption and maximizing the number of users or connections within the available bandwidth.

2. Types of Power Control:

- Downlink Power Control: Implemented by the base station to adjust the transmit power of signals sent to mobile devices. Downlink power control ensures that mobile devices receive signals at the required signal-to-noise ratio (SNR) while minimizing interference to neighboring cells.
- Uplink Power Control: Implemented by mobile devices to adjust their transmit power based on the received signal strength from the base station. Uplink power control helps maintain a consistent quality of service and conserves battery power in mobile devices.
- Open Loop and Closed Loop Power Control: Open-loop power control adjusts transmit power based on predefined parameters such as distance from the base station or channel conditions. Closed-loop power control continuously monitors received signal quality and adjusts transmit power dynamically to maintain optimal communication quality.

3. Power Control Algorithms:

- Proportional-Integral-Derivative (PID) Control: PID controllers adjust transmit power based on error signals derived from the difference between desired and measured signal quality metrics such as received signal strength or signal-to-interference ratio.

- Adaptive Power Control: Adaptive algorithms continuously optimize transmit power based on feedback from the communication channel, adapting to changing environmental conditions, user mobility, or network congestion.
- Fast Closed-Loop Power Control: Fast power control algorithms operate with short feedback intervals, enabling rapid adjustments to changing channel conditions and minimizing fluctuations in signal quality.

4. Challenges and Considerations:

- Channel Variability: Wireless channels are subject to fading, interference, and other dynamic effects, posing challenges for power control algorithms to maintain stable communication links.
- Handover Impact: Power control algorithms must consider the effects of handover events, where mobile devices transition between different cells or base stations, on transmit power levels and communication quality.
- Network Load Balancing: Power control plays a role in load balancing strategies, where transmit power adjustments help distribute traffic evenly across cells or sectors to optimize network capacity and performance.
- Battery Efficiency: In battery-powered devices, power control algorithms must strike a balance between maintaining communication quality and conserving battery life by minimizing transmit power consumption.

5. Impact on Network Performance:

- Improved Coverage and Capacity: Effective power control enhances coverage by ensuring reliable communication links and maximizes network capacity by minimizing interference and optimizing resource utilization.
- Enhanced Quality of Service: Power control contributes to maintaining consistent communication quality, reducing dropped calls, packet loss, and call setup failures, leading to an overall improved user experience.
- Energy Efficiency: Optimized power control strategies help reduce overall energy consumption in wireless networks, extending battery life in mobile devices and reducing operational costs for network operators.

In summary, power control is a fundamental aspect of wireless communication systems, influencing coverage, capacity, quality of service, and energy efficiency. Robust power control algorithms and strategies are essential for ensuring reliable and efficient communication in cellular networks and other wireless technologies.

Bluetooth Slow Hopping Data Rate & spreading Rate Equation

To calculate the effective data rate in a Bluetooth connection considering slow hopping, we need to account for various factors such as packet structure, payload size, and the hopping rate. However, it's important to note that the slow hopping mechanism in Bluetooth doesn't directly dictate the data rate. Instead, it affects factors that contribute to the overall throughput of the connection.

Here's a simplified equation to estimate the effective data rate in a Bluetooth connection considering slow hopping:

Effective Data Rate=Payload Packet size/ Packet Duration

Where:

Payload Size is the size of the payload in each Bluetooth data packet. This payload size typically varies depending on the packet type and Bluetooth version.

Packet Duration is the time it takes to transmit one complete Bluetooth packet, including overhead such as synchronization, header information, and error correction codes.

The effective data rate represents the rate at which useful data can be transmitted over the Bluetooth connection after accounting for overhead and channel utilization. It's important to note that this equation provides a simplified estimate, and the actual data rate experienced in a Bluetooth connection can vary based on factors such as packet loss, interference, and channel conditions.

To obtain a more accurate estimation of the effective data rate, detailed knowledge of the Bluetooth packet structure and the specific implementation of the Bluetooth protocol would be required. Additionally, factors such as retransmissions due to errors and protocol overhead should be taken into account for a comprehensive analysis.

To model the spreading rate in a Bluetooth connection considering slow hopping, we can define it as the rate at which the data is spread across different frequency channels due to frequency hopping spread spectrum (FHSS). We can express this spreading rate as:

The spreading rate represents how quickly the data spreads across different frequency channels due to frequency hopping. It's influenced by factors such as the hopping rate, packet duration, and the specific hopping sequence employed by the Bluetooth devices.

Number of Hops is the total number of frequency hops that occur during the transmission of a packet. For Bluetooth, this would be determined by the hopping rate (e.g., 1600 hops per second) and the duration of the transmission.

Total Transmission Time is the duration of the entire transmission process, including the time spent on each frequency channel, any synchronization overhead, and the time required for packet transmission.

It's important to note that the spreading rate is different from the data rate. While the spreading rate describes how quickly the data spreads across frequency channels, the data rate reflects the rate at which useful data is transmitted over the connection. The spreading rate affects the overall efficiency and reliability of the communication system, particularly in the presence of interference and fading.

Calculating the spreading rate accurately may require detailed analysis of the Bluetooth protocol, including the hopping sequence, synchronization mechanisms, and packet structure. Empirical measurements and simulations under real-world operating conditions can also help validate the spreading rate and assess its impact on system performance.


thank you


BYE