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Research paper

Study and performance analysis of received signal strength indicator (RSSI) in wireless communication systems

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Abstract

The performance of received signal strength indicator (RSSI), which is an evaluated measure of the received power level in the receiver received by a radio frequency (RF) device from the base station sector, access point, or router, is investigated. Long distance weakens and distorts the signal slows down the wireless data rates, thereby leading to a low throughput data. RF signal is measured by the RSSI, which indicates how well a particular radio device can hear remotely connected client radios and is measured by db. Higher or lower RSSI signal than a specific range is undesirable, and call drop issue or link failure will occur. For example, the maximum RSSI of an indoor multipurpose network range should be −75 db to −85 db. This article is organized as follows. The first part presents a brief introduction to the code-division multiple access communication systems. The second part discusses the parameters that affect the quality of RSSI. The third part introduces the practical measurements collected from Iraqcell Telecommunication Company. The fourth part provides the conclusion.

Keywords: *Received Signal Strength Indicator (RSSI); CDMA; Better Coverage Area; Call Drop.*

1. Introduction

People must constantly communicate with one another. High quality of services (QoS) is required to achieve this goal. The received signal strength indicator (RSSI) value provides a clear indicator of the QoS provided by telecommunication companies[1]. The RSSI value of a mobile receiver is preceded by a negative sign, and its unit is dBm. This value is linked to the received signal strength from a tower to a device. In a specific range, a high value of RSSI is preferred[2]. The variation of RSSI value ranges can be attributed to cellular carriers. However, −70 dBm or high contributes to the excellent coverage area of a device with optimum signal strength. Table 1 shows the RSSI value range for 2G and 3G communication systems, and Table 2 shows the RSSI ranges for 4G systems.

Table 1: RSSI Values for 2G and 3G with their Description

RSSI	Signal Strength	Description
>= -70 dBm	Excellent	Strong signal with maximum data speeds.
-70 dBm to -85 dBm	Good	Strong signal with good data speeds.
-86 dBm to -100 dBm	Fair	Fair but useful, fast and reliable data speeds may be attained, but marginal data with drop-outs is possible.
< -100 dBm	Poor	Performance will drop drastically.
-110 dBm	No signal	Disconnection.

Table 2: RSSI Value for 4G with Their Description

RSSI	Signal Strength	Description
>= -65 dBm	Excellent	Strong signal with maximum data speeds.
-65 dBm to -75 dBm	Good	Strong signal with good data speeds.
-75 dBm to -85 dBm	Fair	Fair but useful, fast and reliable data speeds may be attained, but marginal data with drop-outs is possible.
-85 dBm to -95 dBm	Poor	Performance will drop drastically.
<= -95 dBm	No signal	Disconnection.

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2. Code-division multiple access (CDMA)

CDMA standard was originally designed by Qualcomm in the United States, and it was mainly used in the United States and some parts of Asia with other carriers. The CDMA technology utilizes a spread-spectrum technology, in which electromagnetic energy is spread to allow propagation of wide bandwidth signal[3]. CDMA allows large numbers of mobile users to communicate via a shared channel through radio frequency (RF) signals. Data packets are separated and distinguished using special symbols or codes, and then these codes are sent through a wide bandwidth to mobile stations. This standard is becoming attractive for Internet usage due to its high-speed data rate, especially in 3G mobile phones. These standards vary between CDMA and the Global System for Mobile Communications in several countries. As the name implies, CDMA is a multiplexing technique, which allows the propagation of multiple signals through a single transmission channel, leading to the efficient use of bandwidth. The CDMA technology is applicable in ultrahigh-frequency cellular phone systems with frequencies of 800 MHz and 1.9 GHz bands. In addition to the spread-spectrum technology, CDMA systems utilize analog-to-digital conversion[3]. The operation of the CDMA technology includes digitizing the audio signal into binary elements and designing the frequency of the transmitted signal to vary according to a defined pattern (code); therefore, the signal can be received only by a receiver with active frequency processed with the same code and follows up along with transmitter frequency[3]. Large numbers of possible codes can be used to improve the privacy of CDMA systems[3].

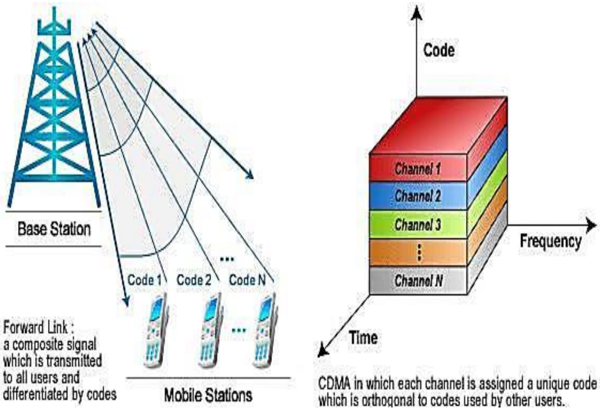

Fig. 1: Code Assignment Process in the CDMA Technology.

3. Handoff in mobile communications

Each time a mobile phone passes between two communication towers, the handoff process occurs between the two towers or possibly between two antennas in the same tower. This process is called handoff or handover[4]. The handoff process maintains the ongoing communication between the users of the network. Handoff has two types: soft and hard handoff)[5]. Hard handoff is a process used in cellular networks and occurs between two base stations or antennas. This process requires a short disconnection from the station to which it was connected to connect to a new terminal. Hard handoff is also known as hard handover or break-before-make handover. This handoff operation is fast, in which the user does not feel disconnected when switching. Hard handoff is also cheaper than soft handover because it requires a single transmission channel.

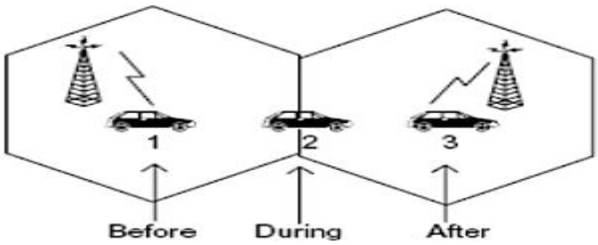

Fig. 2: Hard Handoff Operation.

Soft handoff is the process that occurs when a cellphone user moves between two stations. This process is conducted by connecting with the next station before disconnecting from the old station. If a soft handoff occurs between two different cells, then a mobile phone usually has only one RF receiver. Therefore, both cells must transmit on the same CDMA frequency. The soft handoff process also occurs between two antennas in the same station and is called softer handoff. This process is expensive because it simultaneously uses two channels.

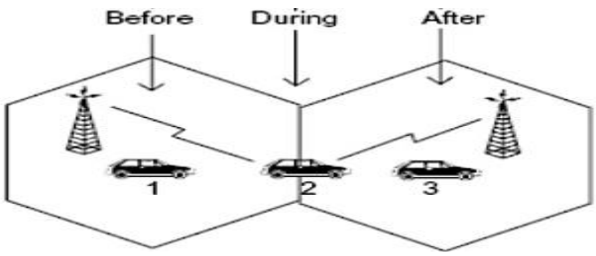

Fig. 3: Soft Handoff Operation.

RSSI is directly related to the handoff process. If the RSSI is in an accepted range, then the handoff process occurs normally; otherwise, the signal will drop.

4. Path loss

Path loss or path attenuation is the reduction in power intensity of electromagnetic waves as it propagates through space. Path loss is the main parameter in design planning of the link budget[6]. Path loss may occur due to different effects, such as free-space loss, refraction, diffraction, reflection, aperture–medium coupling loss, and wave absorption. Path loss is also investigated by terrain contours, environment (urban or rural, vegetation, and foliage), propagation medium (dry or moist air), the distance between transmitter and receiver, and the height and location of antennas, as shown in Fig. 3. This parameter is reversely related to RSSI; when the loss is high, the strength of the received power is weak [6], [7].

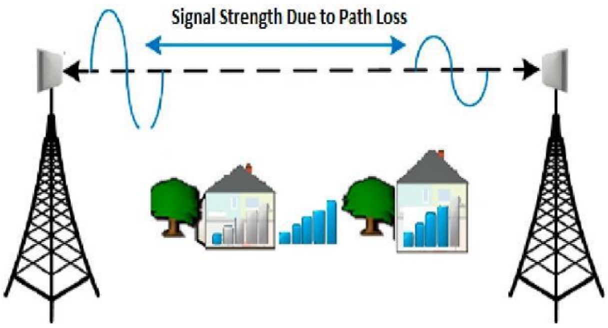

Fig. 4: RSSI As A Function of Path Loss Effects.

5. Broadcasting range and coverage area

The term range refers to the maximum distance at which two radios can operate and maintain a connection. The coverage area can be determined using the formula of the area of a circle πr^2, where r is the radius of the coverage area that is the range of the signal. The coverage area of telecommunication systems is often referred to as a cell, and these terms are usually used interchangeably. The average data rate (tradeoff) between transmitter and receiver is related to range. A high data rate can be achieved in a short range between receiver and transmitter. In an open environment or the so-called free space, power varies inversely with the square of the distance between receiver and transmitter. A short distance between transmitter and receiver leads to high RSSI or amplitude[8]. The antenna gain also increases power, which raises the travel distance of a wireless signal. Path loss can affect the range between transmitter and receiver; if the path loss is increased, then the signal range is decreased[9].

6. Signal-to-noise ratio (SNR)

SNR is defined as the ratio of the power of a signal to the power of background noise.

$SNR = P_{signal}/P_{noise}$,

where P is the average power. The signal and noise power should be measured at the same or equivalent points in a system within the same system bandwidth. High SNR of the system means high RSSI at the receiver[10].

7. Voltage standing wave ratio (VSWR)

VSWR is also referred to as standing wave ratio. VSWR is a function of the reflection coefficient, which describes the power reflected from an antenna[11]. If the reflection coefficient is given by (Γ), then the VSWR is defined by the following formula:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$

VSWR is determined from the voltage measured along a transmission line that leads to an antenna [11], [12]. VSWR is the ratio of the peak amplitude to the minimum amplitude of a standing wave, as shown in Fig. 5.

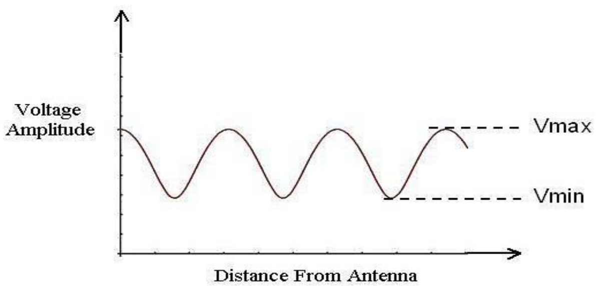

Fig. 5: Measured Voltage Along the Transmission Line.

In Table 1, VSWR contains 36% of the power provided by the receiver reflected from the antenna, and 64% of the power is delivered to the antenna. Notably, the reflected power of 0 dB indicates the reflection of all power (100%), while −10 dB indicates that 10% of the power is reflected. If all power is reversed, then the VSWR will be infinite.

Table 3: VSWR, Reflection Coefficient of Sector No. 11 (Γ), Reflected Power Percent, and Reflected Power in Db Measured by A Site Master Device

VSWR	Γ (s11)	Reflected Power (%)	Reflected Power (dB)
1.0	0.000	0.00	-Infinity
1.5	0.200	4.0	-14.0
2.0	0.333	11.1	-9.55
2.5	0.429	18.4	-7.36
3.0	0.500	25.0	-6.00
3.5	0.556	30.9	-5.10
4.0	0.600	36.0	-4.44
5.0	0.667	44.0	-3.52
6.0	0.714	51.0	-2.92
7.0	0.750	56.3	-2.50
8.0	0.778	60.5	-2.18
9.0	0.800	64.0	-1.94
10.0	0.818	66.9	-1.74
15.0	0.875	76.6	-1.16
20.0	0.905	81.9	-0.87
50.0	0.961	92.3	-0.35

8. Antenna and feeder checking

Antennas and cables must be regularly checked for safety from all conditions or the presence of defects that affect RSSI in one of the antennas. The feeder cable must also be checked for any external damage or damage as a result of the passage of time. A slot of the RRU unit and a tight tie must be installed on a device called site master as shown in Fig. 6 to check the cable. The device shall send a signal inside the cable and receive and measure the ratio between the transmitter and receiver. Knowing the location of the defect in the control is necessary and performed via an option located in the same device to determine if the distance is flawed; the technician then climbs to the place of damage and explores the specific damage or leakage among cables or between the cable feeder and jumper[13].

Fig. 6: Site Master Device.

The following measurements are obtained from Iraqcell CDMA Telecommunication Company from one of the company towers in Iraq. The measurements are taken for three different sectors, and the measurements of the tower are presented as the difference between the main and the divider cables in the RSSI.

- The main cable is the cable that transmits the signal from the antenna to the processing units. The cable and its receiver transmit the signal directly to the scooter from any user to the antenna without any obstacle in the way.
- The divider cable is the cable that comes from the antenna to the processing unit. However, this cable contains the signal that did not originate from the antenna directly and suffered a considerable amount of obstructions, dispersion, and reflection on the signal during movement from the user to the antenna.

```
HW CBTS>
[2019-02-18 08:53:45]
RU0        : Chan 0 Rssi:(Main) -110.1 dbm,(Divs) -110.2 dbm,
Chan 1 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 2 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 3 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 4 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 5 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 6 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 7 Rssi:(Main) N/A dbm,(Divs) N/A dbm,

HW CBTS>
[2019-02-18 08:53:48]
RU0        : Chan 0 Rssi:(Main) -110.3 dbm,(Divs) -110.2 dbm,
Chan 1 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 2 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 3 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 4 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 5 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 6 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 7 Rssi:(Main) N/A dbm,(Divs) N/A dbm,

HW CBTS>
[2019-02-18 08:53:51]
RU0        : Chan 0 Rssi:(Main) -107.2 dbm,(Divs) -110.1 dbm,
Chan 1 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 2 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 3 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 4 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 5 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 6 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
```

Fig. 7: The Difference between Main and DIVs in Sector 0.

```
HW CBTS>
[2019-02-18 09:04:40]
RU2        : Chan 0 Rssi:(Main) -101.4 dbm,(Divs) -102.9 dbm,
Chan 1 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 2 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 3 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 4 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 5 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 6 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 7 Rssi:(Main) N/A dbm,(Divs) N/A dbm,

HW CBTS>
[2019-02-18 09:04:43]
RU2        : Chan 0 Rssi:(Main) -101.4 dbm,(Divs) -103.2 dbm,
Chan 1 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 2 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 3 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 4 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 5 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 6 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 7 Rssi:(Main) N/A dbm,(Divs) N/A dbm,

HW CBTS>
[2019-02-18 09:04:46]
RU2        : Chan 0 Rssi:(Main) -101.4 dbm,(Divs) -102.9 dbm,
Chan 1 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 2 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 3 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 4 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 5 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
```

Fig. 8: Difference between Main and Divider Cables in Sector 1.

```
HW CBTS>
[2019-02-18 09:13:57]
RU4        : Chan 0 Rssi:(Main) -96.5 dbm,(Divs) -102.8 dbm,
Chan 1 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 2 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 3 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 4 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 5 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 6 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 7 Rssi:(Main) N/A dbm,(Divs) N/A dbm,

HW CBTS>
[2019-02-18 09:14:00]
RU4        : Chan 0 Rssi:(Main) -96.1 dbm,(Divs) -99.3 dbm,
Chan 1 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 2 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 3 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 4 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 5 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 6 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 7 Rssi:(Main) N/A dbm,(Divs) N/A dbm,

HW CBTS>
[2019-02-18 09:14:03]
RU4        : Chan 0 Rssi:(Main) -97.7 dbm,(Divs) -100.6 dbm,
Chan 1 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 2 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 3 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 4 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
Chan 5 Rssi:(Main) N/A dbm,(Divs) N/A dbm,
```

Fig. 9: Difference between Main and Divider Cables in Sector 2.

9. Conclusion

RSSI is an important indicator in wireless communication that should be maintained at a specific range of values. This range of values is varied according to signal types (indoor or outdoor) and usage (voice, data, or multipurpose). The performance of RSSI is investigated as a function of many factors as path loss and environments. When the path loss is increased due to any reason, the RSSI will be decreased at the receiver. The range of wireless signal and coverage area and a long distance (range) between transmitter and receiver induce path loss and attenuation, which lead to reduced RSSI at the receiver. High SNR channel yields high RSSI at the receiver. Periodic maintenance for a complete communication system should be applied to avoid any lack in RSSI.

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