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RSSI vs. Digital Link Quality in Wireless Communications

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Abstract

Wireless communications technology has traditionally used receive signal strength indication (RSSI) as the metric to determine the best possible signal quality for receiving and subsequently demodulating transmitted information. However, in modern digital networks, maximum RSSI does not always produce the best link quality, due to undetected bit errors resulting in low packet delivery ratio (PDR). Measurement-based studies have shown that relying on RSSI as a gauge of link quality can be misleading.

As the evolution of digital wireless links has moved to ever higher bit rates, now reaching and exceeding gigabit speeds, the sensitivity of the link quality to PDR and bit error rates has become the dominating parameter for link quality. In the real world, maximum data throughput is the desired feature for a wireless link, not maximum signal strength.

Today, monitoring digital clock recovery and bit error rates to align and monitor high-speed wireless links has proven to be a better quality indicator for high-speed systems, such as 60 GHz wireless gigabit Ethernet links.

Older methodology such as RSSI should be reassessed in light of today's high-speed digital wireless systems. Modern digital methods with a focus on high PDR are becoming the better metric.

Historical Perspective

In the days of analog radio system design, RSSI was typically derived from the automatic gain control (AGC) function. The stronger the received signal, the more the AGC would decrease the gain or amplification factor of the receiver in order to maintain linearity and fidelity.

This meant that a strong received signal indicated a higher AGC signal (also known as the automatic volume control or AVC signal). Often, this signal was also used to drive a front panel meter to indicate the received signal strength, hence the name "S-meter".

Figure 1. Traditional Receiver and S-Meter

Figure 1 is a historical photo of an analog receiver and its S-meter from the early 1970s.[1] The scale used on these older S-meters was in "S-Units" that were based on an arbitrary 1 to 9 strength scale. There were some attempts to standardize the "S-9" signal level to be an equivalent level at the antenna input of 50 microvolts (approximately -73 dBm at 50 ohms). Above the S-9 level, the meters were typically scaled in decibels ("dB above S-9").

As radio technology went from discrete to integrated devices, and analog to digital technology, the receive signal level was renamed RSSI. Today this remains as one of the most used indications of received signal quality.

Digital Networks

In the world of digital networks and communications systems in general, there is an accepted hierarchy that describes the interfaces as layered peer entities, called abstraction layers. This hierarchy is part of the Open Systems Interconnection (OSI) model.[2] In this model, the fundamental unit of measure for information is called the protocol data unit (PDU). The layers of the network are defined in Figure 2 with their associated PDU definitions.

OSI Layer	Description	PDU Definition
Layer 1	Physical	Bit or Symbol
Layer 2	Data Link	Frame
Layer 3	Network	Packet
Layer 4	Transport	TCP/UDP
Layers 5, 6, 7	Application	Message

Figure 2. OSI Layers and Definitions

In the case of an Ethernet point-to-point wireless link, Ethernet frames that incorporate the network-level packets are transported typically in the form of IPV4 packets. Within these packets, other transport overhead, such as TCP/UDP protocol information, is included, along with the final layers for the message payload.

Back down at layer 1, the wireless modulator/demodulator (modem) may then add more overhead such as forward error correction (FEC). All of this digital information is sent over the air serially in the form of a high speed bit stream.

Any communications system composed of copper, fiber and wireless network elements, can be affected by corruption of the data due to distortion and/or noise within the system. A single corrupted bit is defined to be a bit error, and the number of bit errors per unit of time is the bit error rate (BER).

Errored bits or groups of errored bits create what is known as packet loss. Various transmission protocols, such as TCP, will request the sending end of the link or source to resend the information if packets are lost at the destination. Resending packets creates a decrease in overall throughput of the system.

The objective in any modern communications system based on a framed architecture such as Ethernet is to reduce packet loss to a minimum. Network engineers measure the quality of packet reception as the packet delivery ratio, or PDR.

PDR is defined as the ratio of the number of successful packets delivered at the destination divided by the number of packets sent from the source. A system with zero packet loss would have a PDR of 1. As an example, if 10% of the packets are lost (forcing retransmissions), then the PDR would be 0.9.

Link Quality in Wireless Systems

The concept of link quality deals with the parameters of BER and the commensurate PDR that result from bits being corrupted in the system. There are various types of noise and distortion in a wireless system that can impact the PDR, and hence the quality of the link. Wireless interference and noise can corrupt bits during transmission. The sources of interference and noise can vary, but include:

1. Sources of noise/interference outside of the wireless link itself, including high-powered radio sources such as cellular base station transmitters, radar transmitters, broadcast transmitters, microwave ovens, etc.

2. If the received signal level is very low, the natural noise within the electronics of the receiver can create bit errors. This is known as thermal noise or Gaussian white noise.

3. Self interference can be created in a situation where the received signal is impacted by the main or line-of-sight wireless signal in addition to a reflected signal that is delayed in time. This effect is known as multipath distortion and can be significant depending upon the wireless link environment, which may include a variety of reflective surfaces along the link path. Such a signal is said to experience multipath fading.

4. Distortion of the received signal can also occur if the wireless energy is diffracted (rather than reflected) due to edges of buildings or walls, or any other objects that are within the field of view of the transmitted beams.

At the extremely high frequencies used in millimeter wave wireless links, such as 60 GHz and 70/80 GHz systems, interference from other or outside radio transmitters is extremely rare, if nonexistent, simply due to the large difference in the operating frequencies and the very narrow transmission beamwidths, typically on the order of a few degrees.

This is one of the main attractions of using millimeter wave wireless links for high-speed data transmission, since there is an abundance of crowding in the lower frequency spectrum such as the 2.4 GHz and 5 GHz Wi-Fi frequencies.

In terms of weak signals being affected by the natural or thermal noise of the receiver electronics, this is usually mitigated through proper link planning and understanding the maximum rated range for a wireless system. At millimeter wave frequencies, once this parameter is planned for, weak signal conditions are usually not a problem.

Self interference from multipath or diffraction can be an issue when planning a link if the path is either partially obstructed or there are reflective surfaces within the antenna beam pattern of the link. What is important to note here is that multipath signal fading can occur even though the received signal strength at the receiver is strong.

RSSI vs. BER Metrics

The last condition discussed, multipath fading, can create a situation where strong signals are received but the distortion is severe enough such that the BER is high, and hence the PDR is low. Even though a wireless system is capable of indicating or reporting RSSI as a parameter of the link, there are many real world situations in the environment of a wireless link where maximum RSSI does not produce the best quality link due to low PDR.

There has been research in this area of wireless communications technology, and measurement-based studies have shown that relying on RSSI as a measure of link quality can be misleading.[3] Figure 3 is a graph based on

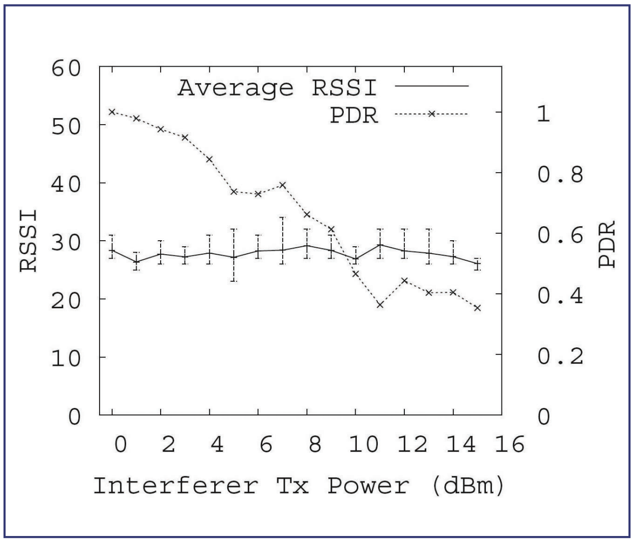

Figure 3. Wireless Link RSSI and PDR with Interference[3]

actual measurements from a link experiencing interference that shows RSSI and PDR. Note that as the interference level is increased and the PDR is reduced, the RSSI level remains essentially constant.

This is a very important consideration because the traditional method used to align point-to-point wireless links is usually based on the RSSI level. Also, network management parameters (represented by the management information base, or MIB) often use RSSI in an attempt to monitor the quality of the wireless link.

However, as the evolution of digital wireless links has moved to higher bit rates, up to and exceeding gigabit speeds, the sensitivity of the link quality to PDR, and hence BER, has become the dominating parameter for link quality. After all, maximum data throughput is the desired feature for a modern wireless link, rather than maximum signal strength.

There are methods that make use of monitoring digital clock recovery, or synchronization, and BER indication to align and monitor high-speed wireless links, and it has proven to be a better quality indicator for gigabit speed systems.[4]

Conclusion

Older methods such as RSSI used to indicate proper link alignment and monitoring of link quality should be reassessed in light of higher-speed digital wireless systems, such as wireless gigabit Ethernet. RSSI has been the approach used for decades in this area, but as the speed of the link continues to increase into the gigabit range and beyond, the potential for bit errors will continue to increase as well. Today, modern digital methods focused on BER are becoming the better metric to measure link quality.

About Vubiq Networks

Vubiq Networks, Inc. is a broadband wireless networking company focused on multi-gigabit systems using its 60 GHz millimeter wave technology for metropolitan Ethernet wireless fiber extension, campus building connectivity, and 4G/LTE advanced network backhaul. Vubiq's HaulPass V60™ product is an innovative wireless fiber-optic extension solution delivering quality of service, gigabit Ethernet transport speeds, and advanced networking features. HaulPass V60 deployments use metrics such as PDR, not RSSI, to establish optimum link quality.

Vubiq Networks is based in Irvine, CA.
Learn more at www.vubiqnetworks.com.

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