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Video Monitoring Application Using Wireless Sensor Node with Various External Antenna

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Abstract

Surveillance and monitoring has become very important for security reasons these days. The use of wireless sensor node device offers a variety of platform depends on the attached sensor. When an image sensor is attached, the wireless sensor node is capable of monitoring an area wirelessly. Since wireless environment uses antenna to transmit and receive data, antenna is an important component that affects the video monitoring performance. This paper describes a surveillance system using Raspberry Pi with various external antenna. The Raspberry Pi with Pi Camera module and various types of antennas was used for testing and experimentation in line-of-sight (LOS) and non-line-of-sight (NLOS) condition. The results revealed that the Yagi Uda antenna gives the best output in terms of its signal strength and average Receive (Rx) rate.

Keywords: *wireless sensor node, raspberry Pi 3, line-of-sight & non-line-of-sight*

1. Introduction

Recently, there has been a rise in video surveillance system in public and private surroundings due to an increasing consciousness of security. Factories, hospitals, supermarkets, hotels, army base, schools, and companies are having their own monitoring and surveillance system to function 24/7. The popular traditional surveillance system, closed-circuit television (CCTV), provides real-time monitoring, surveillance footage, and giving authorities evidence against illegal actions [1]. It is enabled by high end cameras, video servers, network switch and monitoring computers. All these resources lead to complexity, high expense, high power consumption, and also requires more area to be properly established.

To further reduce the cost, complexity, and power consumption, IP-based data delivery cameras are developed and mass produced. However, most of the IP cameras require high bandwidth, thus involving this as a major drawback. Performance of the IP cameras are assessed with respect to their video resolution, power dissipation, bitrates, distortion, frame rates, and network bandwidth [2]. Numerous projects and processes use Raspberry Pi as an IP-based camera wireless sensor node for surveillance and monitoring. It is the best to implement as a sensor node since its price, processing power; memory capacity, connectivity, and multipurpose usage overpower other types of sensor node [3].

Raspberry Pi is a credit sized card, low cost single board computer. It contains many features that are embedded to a single board such as GPIO pins for interfacing sensors and switches, Ethernet port, USB ports, HDMI port to interface with monitor, camera port and an audio jack. A micro SD card is used as the hard disk for the operating system. For the purpose of surveillance system, Raspberry Pi operates as the brain that perfoms the complete control of the system. A Pi camera module is mounted together on the boards CSI connector where the camera features a HD display of image [4].

Raspberry Pi has the capability to stream videos, similar to the IP cameras where the video can be displayed on a web browser. A lot of papers on the development of video monitoring using Raspberry Pi mostly focus only on the system architecture using wireless adapter without taking the consideration of specification of the antenna used. Hence, the same

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types of antenna are used which is the monopole or ceramic chip type antenna. In this system, we use Raspberry Pi 3 as the microprocessor attached together with a Pi camera module. External antenna is connected to the Raspberry Pi main board through a coaxial cable. The system monitors a specified area wirelessly including other features such as recording, motion detecting, and also offers the ability to change the video resolution.

The utilization of antenna highly affects the execution of data transmission in terms of its signal strength, throughput, thus affecting the real-time video performance. Hence, various types of antenna were used for practical experiment to test the effectiveness of the video consistency in displaying image relating to its frame rate and lagginess in line-of-sight (LOS) or non-line-if-sight (NLOS) situation. The antennas used as shown in Figure 1 are the Raspberry Pi 3 onboard antenna, monopole antenna, Fractal Koch antenna, and the Yagi Uda antenna. Yagi Uda was develop according to [5-7] and Fractal Koch designed according to [8], [9] by the Adavance RF and Microwave Research Group in Universiti Teknologi Malaysia (UTM).

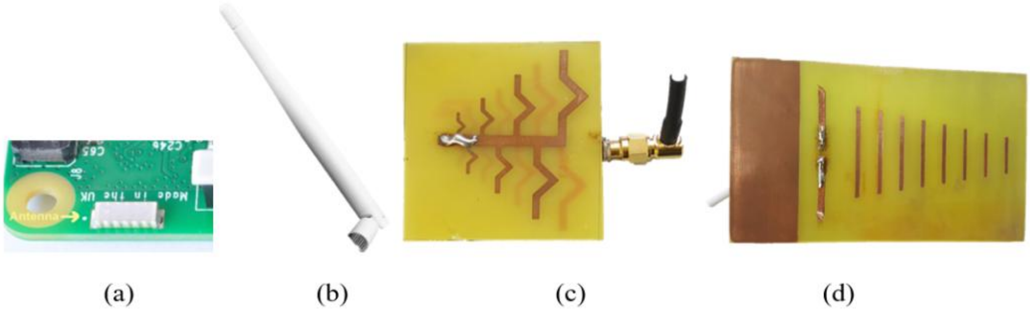

Figure 1. (a) Raspberry Pi 3 onboard antenna, (b) TP-Link TL-WN722N monopole antenna, (c) Fractal Koch antenna, and (d) Yagi Uda antenna

The antenna specifications are given im Table 1:

Table 1. Antenna specification

Antenna	Raspberry Pi 3	Monopole	Fractal Koch	Yagi Uda
Radiation Pattern	Omni-directional	Omni-directional	Directional	Directional
Frequency	2.4 GHz	2.4 GHz	2 - 3 GHz	2.4 GHz
Gain	<1 dBi	4 dBi	4.5 dBi	6.3 dBi

A sensor node with a Yagi external antenna is shown in Figure 2:

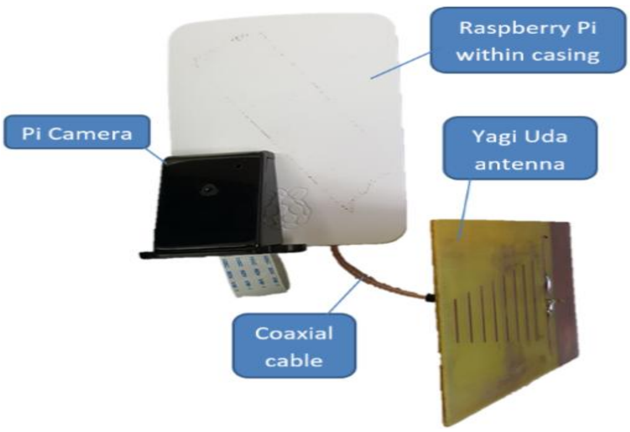

Figure 2. Sensor node with Yagi Uda antenna

2. System Model

To stream video from Raspberry Pi to PC, MJPG-streamer technique is used. MJPG-streamer is a command line application that copies JPG-frame from a single input plug-in to multiple outputs plug-in. It can be used to stream JPEG files over an IP-based network from webcam viewer like Firefox, Google Chrome, Video LAN client or even to a Windows Mobile device [10-11]. Since web browser displays the video from Raspberry Pi, a Graphical User Interface (GUI) is optional to be developed. The interface was design according to Rpi Cam Web Interface where it can store static and recorded images within the Raspberry Pi, download the saved files at PC, and also has motion detection record capabilities [12-13].

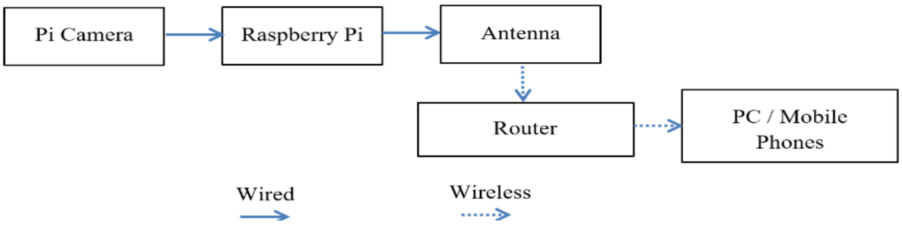

Figure 3. Blok diagram of a sensor node for monitoring system

Figure 3 shows the block diagram of a wireless sensor node with an external antenna enabled by the flexibility and scalability of Raspberry Pi.

a. Sensor

Pi Camera module features a 5 MP with fixed focus lens, has the capabilities of capturing 2592 × 1944 pixel static image, and supports 1080p, 720p, and 640 × 480p video.

b. Raspberry Pi

Raspberry Pi 3 Model B is used and is driven by 1.2 GHz 64-bit quad-core ARMv8 CPU and 1 GB RAM. Different from the previous models, Raspberry Pi 3 has a built-in 802.11n wireless LAN antenna. In this system, Raspberry Pi sends the live video data from the Pi Camera to the PC. The interface GUI displayed at the PC is programmed inside the Raspberry Pi. Since four wireless sensor nodes were installed, each Raspberry Pi was configured with a static ip address.

c. External antenna

Antenna is used to send and receive data wirelessly. A coxial cable connected with an external antenna is mounted onto the Raspberry Pi 3 board by removing the previous onboard antenna as shown in Figure 4.

Figure 4. Coaxial cable soldered onboard

d. Router (Mikrotik)

Router is to forward the data packets between PC and Raspberry Pi. Mikrotik model used is the RB941-2nD-TC model where it has an antenna with a gain of 1.5 dBi and transmitter power up to 158 mW (22 dBm). Mikrotik is a router that provides routing and wireless equipment for all possible uses including viewing the network performance.

e. PC (Monitoring and Analyzing)

Receive data from Raspberry Pi and display the video on web browser. The performances were analyzed using Winbox software for Mikrotik.

3. Results and Analysis

To obtain the best performance for video monitoring is truly a complicated task since there are a lot of aspects to be considered. A research on every detail must be done to achieve better understanding thus, leading to better results. This paper generally focussing on the implementation of different antennas, to observe the differences of output performance of the system. The signal strength and the transmission rates were observe using Winbox software.

Practical implementation was made in several stages of development. The best channel was selected to perform the test since 2.4 GHz WiFi channel frequencies that consist of 14 channel numbers. The first stage of the development involves LOS propagation test where the signal strength of the system is tested using various antennas in contrast to distance. Signal strength yields inconsistent result even though a sensor node is setup on a fixed position. Therefore for practical testing, the highest threshold signal strength was recorded for every 10 meters. Figure 5 shows the signal strength obtained from Winbox. Raw data of all the output was recorded and converted into graph using Sigma Plot software as shown in Figure 6.

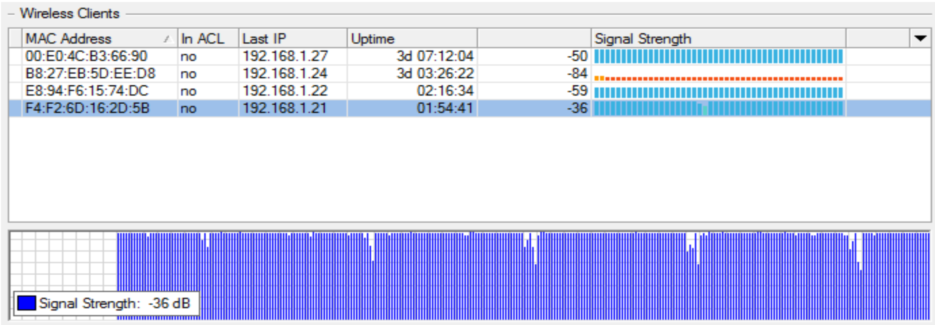

Figure 5. Camera 1 signal strength in Winbox

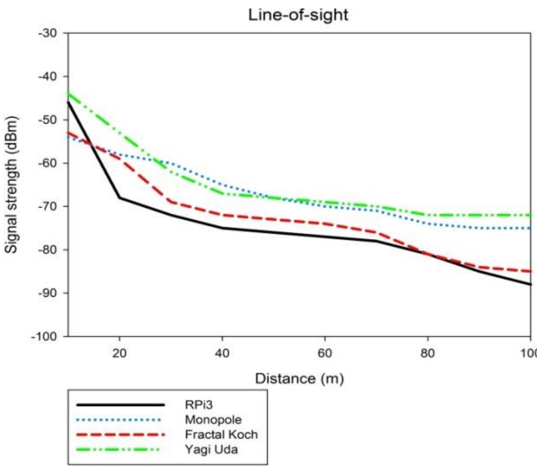

Figure 6. LOS signal strength

As shown from the results, all of the antenna for the first 10 meters gives a range of -44 dBm to -54 dBm which is in a good signal strength range. The signal strength starts to decrease when the sensor node position is placed further from the router. Hence, the longer the distance, the lower the signal strength. Consequently, at 100 meters distance, it shows that Yagi Uda yields a signal strength of -70 dBm which is the best, followed by the monopole that gives -72 dBm, then the Fractal Koch which produce -88 dBm and lastly the Raspberry Pi 3 antenna, -90 dBm. This shows that the best antenna to use for LOS propagation test in term of long distance is the Yagi Uda antenna and the monopole antenna. Further more, the video starts to lag when the signal strength is around -60 dBm and above. So, for video monitoring, using Raspberry Pi antenna and the Fractal Koch is best at 20 meters to 30 meters range distance for LOS condition and for the Yagi Uda and monopole antenna, 40 meters to 50 meters distance is still within a good range.

The next stage of experiment is held around the P18 UTM laboratory. Four sensor node were set up fixed in four different positions. Figure 7 shows the laboratory layout with fixed sensor node (camera) position. Obstacles such as walls and other interferences are also taken into account. The network was configured according to star topology connection where four sensor node is connected wirelessly and a PC is connected using LAN cable to the router. Camera 1 and camera 2 was installed within the same room as the router, whereas camera 3 and camera 4 were installed outside and is interfered by obstacles such as walls. Camera 1 positioned is very near to the router. The distance from router for camera 2 and camera 3 are roughly the same around 10 meters, but the only difference for camera 3, it has a wall obstacle in its way. For camera 4, it is situated in the meeting room 20 meter from the router. In this case, the signal strength was recorded for 1 minute for each fixed sensor node.

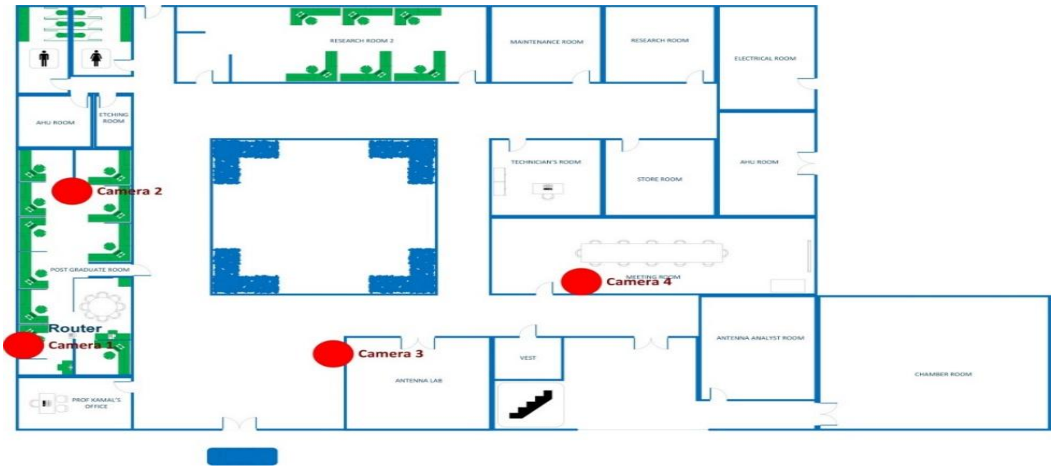

Figure 7. P18 UTM laboratory

Figure 8 shows the results of signal strength average for every 10 second in 1 minute. Since camera 1 is installed near to the router, all antenna yields optimum output from -31 dBm to -43 dBm. There is a slight difference in signal strength but monopole antenna and Yagi Uda antenna gives better output compared to the others. From all of the sensor node camera, it is observed that Yagi Uda gives the best signal strength in the range of -31 dBm to -74 dBm, followed by the Fractal Koch from -37 dBm to -81 dBm, monopole from -32 dBm to -78 dBm, and lastly the Raspberry Pi 3 antenna from -39 dBm to -87 dBm. This shows that Yagi Uda gives the best signal strength in LOS and NLOS condition. The monopole and Fractal Koch produce roughly the same result because both has nearly the same gain rating or dBi. On the other hand, at camera 2 position, it is observed that Fractal Koch is better for LOS in 10 meters distance but produce roughly the same output with monopole for NLOS condition.

Receive (Rx) rate performance is also obtained from the Mikrotik Winbox software. The term Rx is define as the data received from sensor node at Mikrotik. Using different antennas gives different Rx output performance. Hence, differences can be seen when distance is added or obstacle interference is in the way. Image resolution is also an important factor that affects the sensor node video performance. The lowest video image resolution is selected which is 768×576 pixels. The effect using a higher image resolution are not discussed in this paper. The Rx rate was obtained from Winbox as shown in Figure 9 and is entered into Table 2.

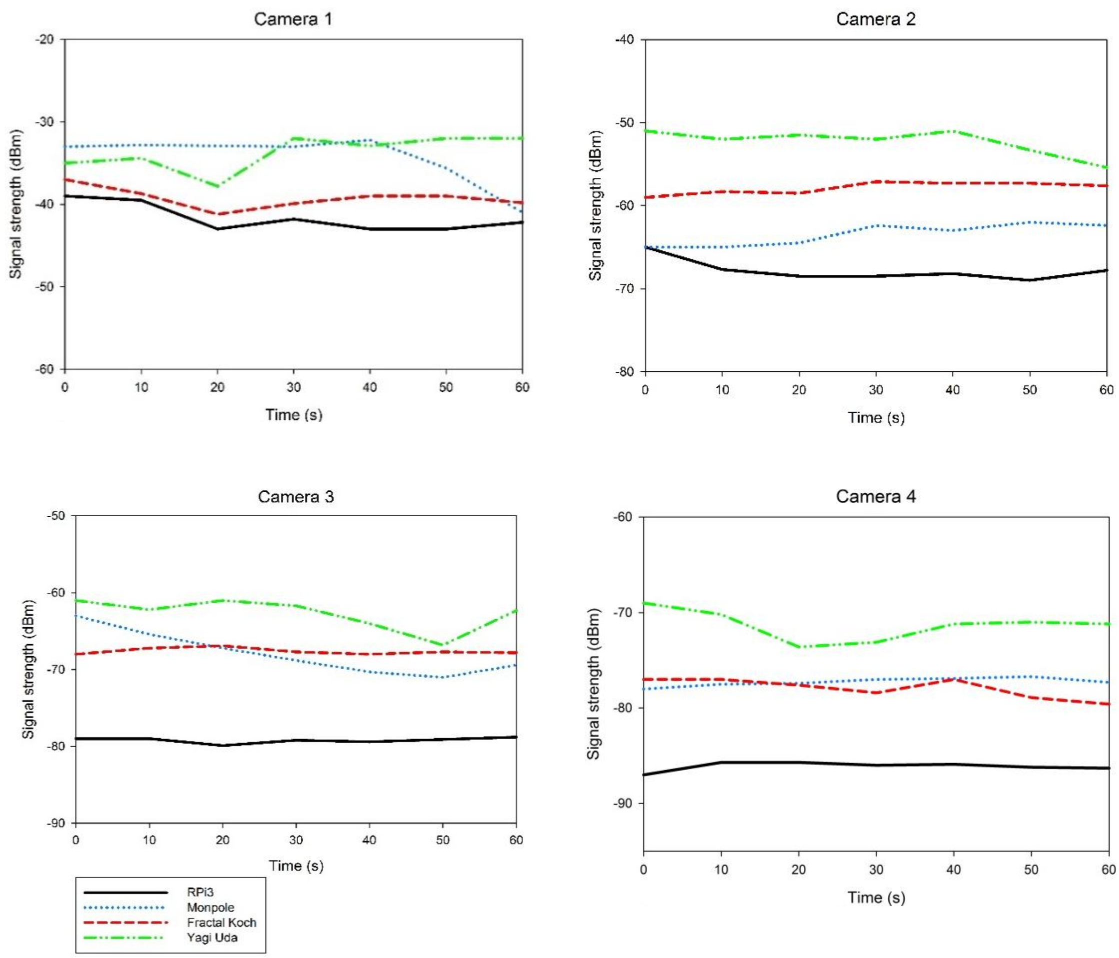

Figure 8. Signal strength for camera1, camera 2, camera 3 and camera 4

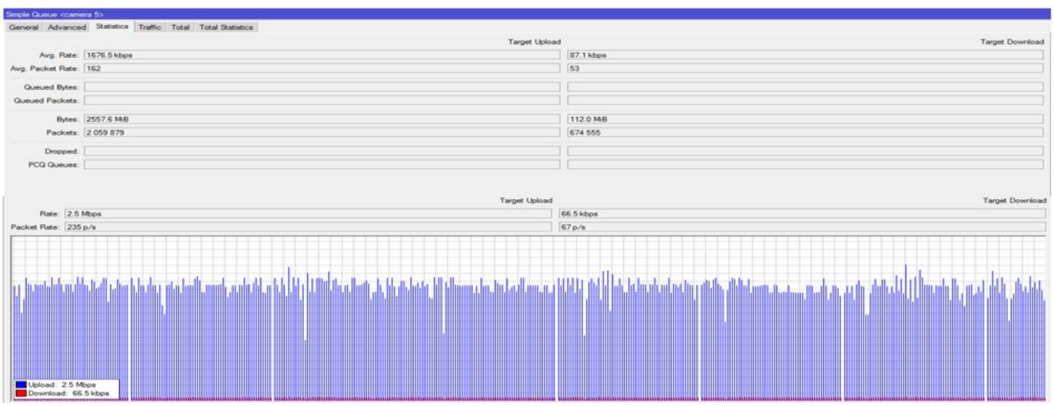

Figure 9. Winbox data rates interface

Table 2. Rx rates average for 10 minutes

Antenna Type	RPi 3	Monopole	Fractal Koch	Yagi Uda
Sensor node	Rx (kbps)	Rx (kbps)	Rx (kbps)	Rx (kbps)
Camera 1	79.4	79.8	80.1	80.8
Camera 2	77.9	81.7	76.0	84.3
Camera 3	76.4	78.6	79.0	81.9
Camera 4	36.4	61.3	45.3	72.4

From the results obtained in Table 2, 10 minutes of average Rx rates were recorded. For camera 1, camera 2 and camera 3, the differences in Rx rate are negligible. All antennas gives nearly the same Rx rate since all cameras are within the range of 10 m even though camera 3 are placed behind a wall. Since camera 4 is the furthest position, differences in Rx rates for the 10 minute average is detected. Mikrotik receive best data rate of 72.4 kbps when using the Yagi Uda antenna. Monopole yields the second best Rx of 61.3 kbps, followed by the Fractal Koch antenna which is 45.3 kbps. Raspberry Pi onboard antenna gives 36.4 kbps, which is the least average data rate to be received at Mikrotik. There was lesser lagging issue detected at camera 4 when using Yagi Uda antenna. From all the results obtained, it shows that the Yagi Uda produce the best LOS and NLOS output for both signal strength and Rx rate. Since antennas only affects the wireless transmission of data, it is also applicable for other type of sensor node besides Raspberry Pi.

4. Conclusion

The performance of the Wireless sensor node system can be improved by many considerations. Sensor node specifications such as processor, RAM, and storage capacity also affects the system. Besides that, the program used to design the system to be streamed and its video resolution also gives huge effect on the video performance. But, all of these components cannot operate on wireless smoothly without an antenna. Antenna gives impact on the data transmission, hence using a better antenna will result in better performance. Another improvement to the system can be done by using a wireless adapter with detachable antenna which is connected to the USB port of the Raspberry Pi. Wireless adapter can give a boost to the antenna performance in term of transmission speed where some adapters can perform speed up to 150 Mbps and above.

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