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Design and implementation of centralized reading system on analog postpaid water meter

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Abstract. Local water supply company in Indonesia still uses analog water meter, hence the data recording of customer' water usage was carried out by officers manually. It is certainly an inefficient and risky method that could produce errors. Moreover, not all water meter data could be recorded at the time officers come to the location, for example in vacant houses, that could causing customers suffer the consequences such as fine for late payment. In this study, we proposed a new water meter reading system design which contains a conversion device that could convert analog water usage data into the digital one, installed in existing analog meter. The converted data would be transmitted to local concentrator using a 433 MHz wireless transceiver network and sent to the server that acts as monitoring center via cellular networks. The process of digitizing the water meter does not need to be done by replacing the existing analog water meters. Thus, the investment costs of the water meter digitalization process would be relatively cheaper and it could be a solution for increasing the recording efficiency and accuracy of customer's water usage data.

1. Introduction

Existing post-paid customer water meter readings are still carried out very traditionally, by visiting the customer's home by an officer of a local water supply company who then records them by photographing using a smartphone and then inputting the data to a computer for processing as a reference for making billing forms to the customer. This water meter recording process model is very risky for errors, so there are often complaints, especially about the number of bills to be paid by customers. The biggest impact is that customers often feel disadvantaged only because of mistakes made by officers in the case of recording a manual water meter because of the existing water meter device which is still analog. Local water supply companies certainly have a great responsibility to be able to provide solutions to problems like this, especially those that have to do with the handling of frequent human error officers in reading meters and entering data manually into the system.

This problem will be solved by changing the system by replacing existing analog water meter devices into digital [1], so that all processes can be done in automatic, by including application software for monitoring, warning, and reporting.

On the other hand, technological developments in automation, telemetry and telecontrol are more than enough to support the digitalization and automation of water meters that are still traditional [2]. However, if this digitization process is carried out simultaneously by replacing all analog devices into digital, then it will certainly require a very large cost, especially if these costs are distributed to the customer, new problems will arise in the community.

Therefore, this research will be able to provide a solution to the problems mentioned above, by installing a device for the conversion of analog data from the existing postpaid water meter readings in the form of images into text data. Then the text data will be sent to the server using wireless-based communication [3]. Data that has arrived at the server can be processed as needed, both for the basis of making bills to customers and for reporting purposes in real-time.

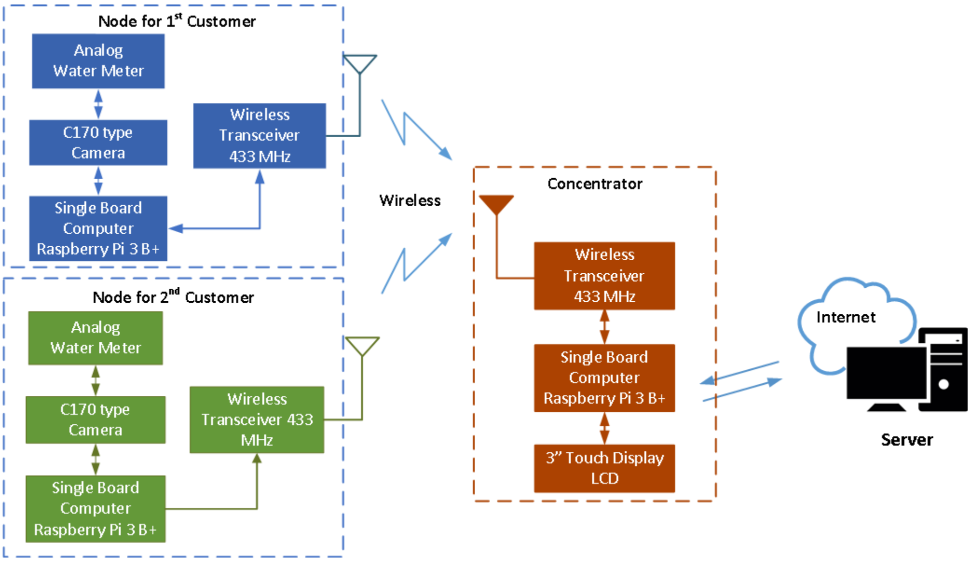

Figure 1. Centralized reading system on Analog water meter.

The centralized postpaid analog water meter reading system is designed according to the block diagram in figure 1. The system consists of 3 (three) main equipment parts, namely; (1) A node is a piece of equipment installed in an existing water meter for each customer and is tasked for converting photographic data from the nominal reading of water usage on an analog postpaid water meter [4] through a camera to become data text that is ready to be sent to the concentrator section, (2) The concentrator is the part that coordinates and recording the text data received from a number of nodes in the vicinity, and (3) The server is who acts as the monitoring center of the results of the nominal reading of water usage by a number of customers through a concentrator and will subsequently be processed into a basis making billing to customers, and others in accordance with management needs including reporting related to water usage trends in one particular area.

Water meter reading is carried out by a camera mounted in an upright position to a series of analog water meter numbers using photographed, so that the resulting data is in the form of an image with a .jpg format [5]. This image data is used as a converter input to be converted into text data [6].

Conversion of image data into editable text is performed using the Optical Character Recognition (OCR) method [7]. This OCR conversion method is available in software form, such as; Desktop OCR, OCR Server, Web OCR and others, with an accuracy that varies from 71% to 98%. OCR software that is open source and free is Tesseract [8,9].

The process of character recognition using OCR Tesseract [8], shown as in Figure 2 below.

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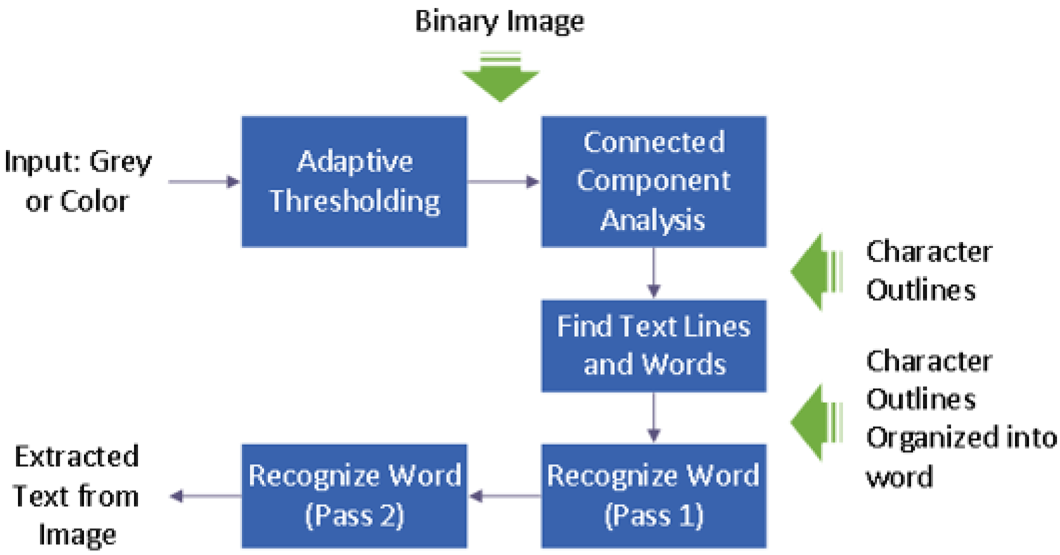

Figure 2. Architecture of OCR tesseract.

Adaptive thresholding is the process of determining the threshold value to separate between an object and the background of a greyscale image, is carried out per pixel and per sub-image with size m x m, which repeats until all of the image areas has been processed [10]. The process of determining the threshold is [11]:

$$T = \frac{\max(Sub_{image}) - \min\,(Sub_{image})}{2} \qquad ;\text{ varians} > 100 \tag{1}$$

$$T = \frac{\max(image) - \min\,(image)}{2} \qquad ;\text{ varians} \leq 100 \tag{2}$$

where,

$$varians = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1} \;;\text{ and } \quad \bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{3}$$

If the variance is ≤ 100, the threshold value T is used as the basis for determining output in the form of binary data. But if the variance is ≥ 100 the T value is used based on the global thresholding process, as follows [12]:

- Divide the image area into two regions, $R1$ and $R2$, using the value T calculated from equation
- Calculate the average value of intensity $\mu1$ and $\mu2$ for each region $R1$ and $R2$
- Calculate the new T threshold value with the formula $T = (\mu1 + \mu2)/2$.
- Repeat steps (2) and (3) until the values $\mu1$ and $\mu2$ do not change again. And T for the base determines binary output.

The output of the thresholding process becomes a binary form, carried out using equation [9]:

$$g(x,y) = \begin{cases} 1 & if \quad f(x,y) \geq T \\ 0 & if \quad f(x,y) < T \end{cases} \tag{4}$$

Where,
g(x,y) : matrix of image binary value
f(x,y) : matrix of images greyscale value

Analysis is performed on the connected components to determine where the outline components are stored. Outlines are collected together and become BLOB. Blobs are arranged into text lines, while lines and regions are analyzed to become fixed pitch and proportional texts. Lines of text are broken up into words according to character spaces. Text with pitch is divided by each character cell, then proportional text is broken up into words using fuzzy spaces.

The first pass separates words that are already in the database, and the second pass is the recognition of words in the image.

2. Method

The research was carried out for the design, construction, and implementation of a centralized analog postpaid water meter reading system, using a 433 MHz wireless transceiver network and cellular modem to be connected directly to the internet network, including:

- Designing and manufacturing a Node device for reading water usage on an existing analog water meter using a camera, and the results of the image are converted to text characters, then sent to the concentrator using a wireless transceiver with a frequency of 433 MHz.
- Design and manufacture of concentrator devices, whose act is to store text character data from several nodes that are responsible for it, store it on the microSD memory provided and parallelly store it on the database server using the internet network.
- Design and manufacture of application software to process data from the result of customer's water usage from all nodes/ customers to be used as a basis for web-based reporting, both for the benefit of the Company's administration and for customers. Programs created using PHP with a MySQL database.

2.1. Device specifications

The main component of this water meter reading system conversion consists of; (1) Cameras, (2) single-board computers of Raspberry Pi, and (3) 433 MHz wireless transceiver. The subsections of the devices above each have the following specifications.

2.1.1. Camera. The camera used is a type of Webcam C170 camera, a 720p HD type camera. Capturing photos can reach sizes of up to 3 Mega Pixels (in software) and can be adjusted automatically in poor lighting conditions, to produce images that are good enough and ready to be converted into text data. The detailed specifications of this camera can be shown in table 1 below.

Table 1. C170 type camera specification.

Parameters	Specification
Connector type	High Speed USB 2.0
Lensa and sensor type	Plastic
Focus type	Fixed
Optical Resolution (True)	1280 x 960 1.2MP
Image Capture	- (4:3 SD) : 320x240, 640x480, 1.2 MP, 3.0 MP - (16:9 W) : 360p, 480p, 720p
Video Capture	- (4:3 SD) : 320x240, 640x480, 800x600 - (16:9 W) : 360p, 480p, 720p
Frame Rate (max)	30fps @ 640x480

2.1.2. Single board computer Raspberry Pi. The Raspberry Pi used is the Raspberry Pi 3 Model B+, which is the newest product in the Raspberry Pi 3 line, which offers a 64-bit quadcore processor and runs at 1.4 GHz, dual-band 2.4GHz and 5 GHz wireless LAN, Bluetooth 4, 2 / BLE, faster Ethernet, and PoE capabilities via HAT PoE separately.

The detailed specifications of the single-board computer of Raspberry Pi 3 B + used in this research are as in table 2 below.

Table 2. Raspberry Pi 3 b+ specification.

Parameters	Specification
Processor	Broadcom BCM2837B0, Cortex-A53 64-bit SoC @ 1.4GHz
Memory	1GB LPDDR2 SDRAM
Connectivity	2.4 GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, BLE Gigabit Ethernet over USB 2.0 (maximum throughput 300Mbps) 4 × USB 2.0 ports
Access	Extended 40-pin GPIO header
Video & sound	1 × full size HDMI MIPI DSI display port MIPI CSI camera port 4 pole stereo output and composite video port
Multimedia	H.264, MPEG-4 decode (1080p30); H.264 encode (1080p30); OpenGL ES 1.1, 2.0 graphics
SD card support	Micro SD format for loading operating system and data storage
Input power	5V/2.5A DC via micro USB connector 5V DC via GPIO header Power over Ethernet (PoE)–enabled (requires separate PoE HAT)

2.1.3. Wireless transceiver 433MHz. The Wireless Transceiver used is the LoRa SX1278 type which works at a frequency of 433 MHz, a feature of LoRa^{TM} that provides ultra-long range is the spread of the communication spectrum that protects against interference (noise) including minimizing power consumption. Using the LoRaTM modulation technique patented by Semtech SX1278 can reach sensitivity up to -148 dBm. Details of the specifications of this type of wireless transceiver are shown in Table 3 below.

Table 3. Spesifikasi transceiver LoRa module SX1278.

Parameters	Specification
Operating voltage	DC 1.8 V – 3.7 V
Frequency range	137 - 525 MHz
RF Input Level	+10 dBm
Modulation	FSK/OOK/LoRa^{TM}/GMSK/MSK
Bandwidth	7.8 – 500 kHz
Effektive bit rate	0.018 – 31.5 kbps
Receiver sensitivity	-111 dBm to -148 dBm
Operating Temperature	-40 °C to +85 °C
RF Output Power	+20 dBm
Range	3 – 5 Km
Dimension	20.5x 15.5 x 2.0 mm

2.2. Systems design
The centralized reading system on analog postpaid water meter consists of 3 sub-section of devices, each of which can be shown in the following.

2.2.1. Node device. The node as the main device that is placed in the customer's water meter, whose task is to read the existing analog water meter numbers which are controlled by a single board computer of Raspberry Pi 3 B +, which is designed according to the following block diagram.

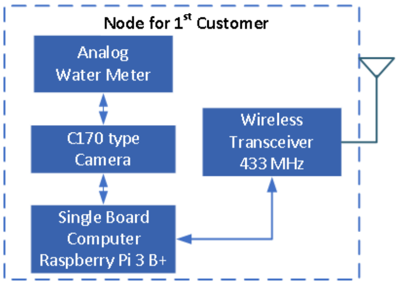

Figure 3. Diagram block for Node system design.

The camera is mounted in a position perpendicular to the water meter with a distance that has been set, so that the focus point is precisely located on the surface of the water meter character would be read. single board computer of Raspberry Pi as a control for both starting and stopping water meter reading, converting image data into text characters or instructing transceivers to transmit data that is ready to be sent (default Transceiver is Receive). single board computer of Raspberry Pi uses an external voltage source of 5V / 3Ampere. Schematic of the circuit of this Node device, as shown in figure 4 below.

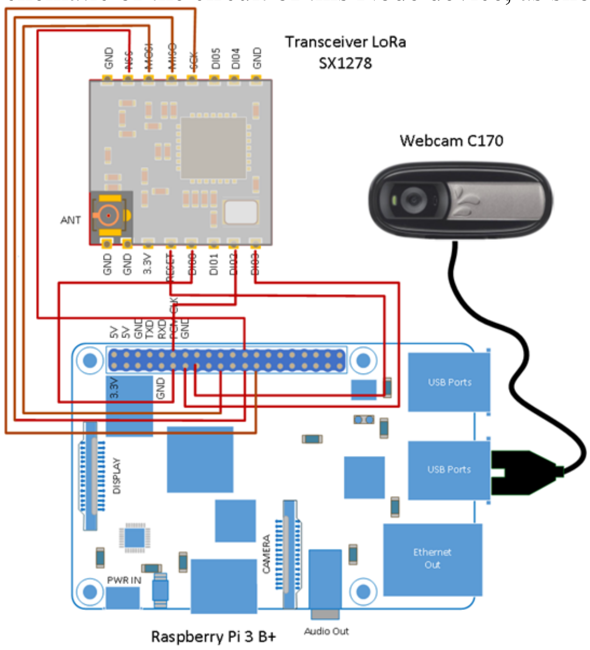

Figure 4. Circuit schematic of the Node device.

Based on Figure 4 above, the connection between the camera and single-board computer of the Raspberry Pi is to use a High-Speed USB 2.0 connector. And the wiring diagram of the Raspberry Pi module with a 433 Mhz transceiver is as follows.

Table 4. Wiring diagram Raspberry Pi to 433 MHz transceiver.

Raspberry Pi 3 B+	Transceiver 433 MHz
GIPO26	RESET
GPIO17	DIO0
MOSI	MOSI
MISO	MISO
CLK	SCK
SPI_CE0	NSS

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2.2.2. Concentrator. The concentrator is designed to be able to work as a trigger to instruct the working node to do its job. The concentrator also acts as a receiver of data sent from a number of nodes to then be stored on a micro-SD card memory and in parallel sent to the server database.

Data stored on this micro-SD is used as data redundancy for maintenance needs, which can be retrieved manually by the Officer if necessary. The data saved is the most recent data received (default storage is Replace). This concentrator is also equipped with a 3 inch LCD Touch Display. This system is designed according to the block diagram in figure 5 below.

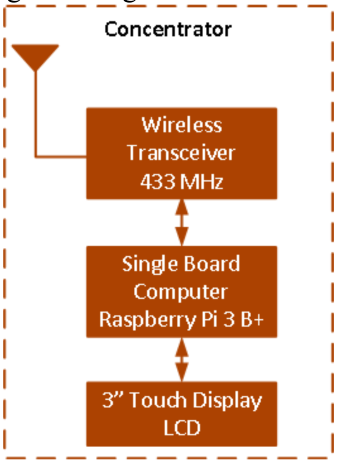

Figure 5. diagram block of concentrator.

For data communication to the server using a cellular modem is used. This Concentrator circuit scheme is shown in Figure 6 below.

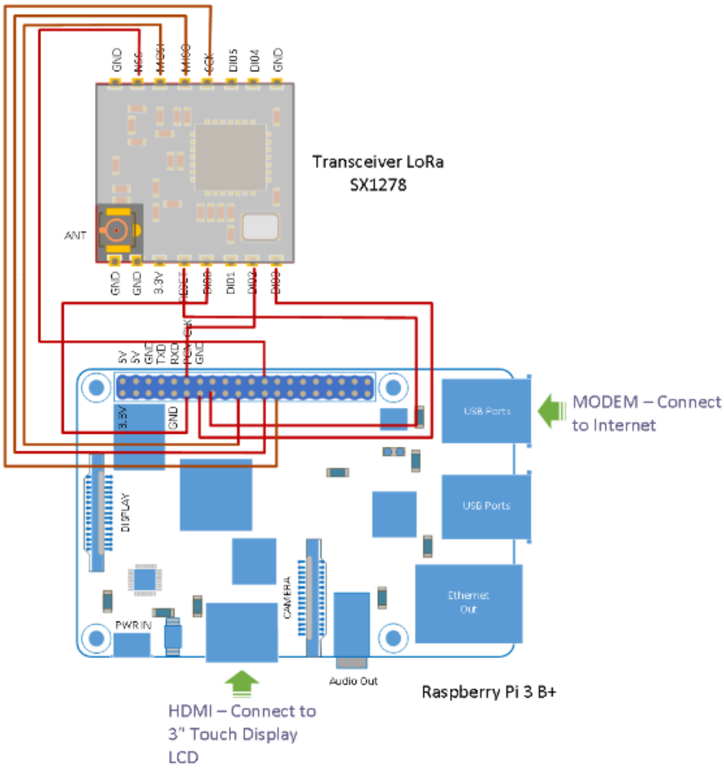

Figure 6. Circuit schematic of Concentrator.

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The wiring diagram used between the Raspberry Pi module and the 433 Mhz transceiver as shown in Table 5 below.

Table 5. Wiring diagram Raspberry Pi to 433 mhz transceiver.

Raspberry Pi Zero	Transceiver LoRa SX1278
GPIO22	RESET
GPIO17	DIO1
GPIO18	DIO2
GPIO26	DIO3
MOSI (GPIO10)	MOSI
MISO (GPIO9)	MISO
CLK (GPIO11)	SCK
SPI_CE0	NSS

Data received by the server is stored in a database created using My-SQL and displays of the results using the PHP program. Through this PHP program, data can be processed according to needs, especially to be connected to the creation of billing, reporting needs to the management of the Company as well as to public information especially to customers, etc.

3. Results and discussion

The results of this research are prototype an existing analog water meter reading system that is carried out centrally. This system supports the process of digitizing water meters which are carried out without replacing the existing water meters that have been installed in each customer, so the issue of the amount of investment used in the process of digitizing water meters in one particular area is no longer an obstacle [13].

3.1. The results of designing a centralized water meter reading

The results of the design of the device used to perform a centralized reading of the water meter are shown in Figure 7 below.

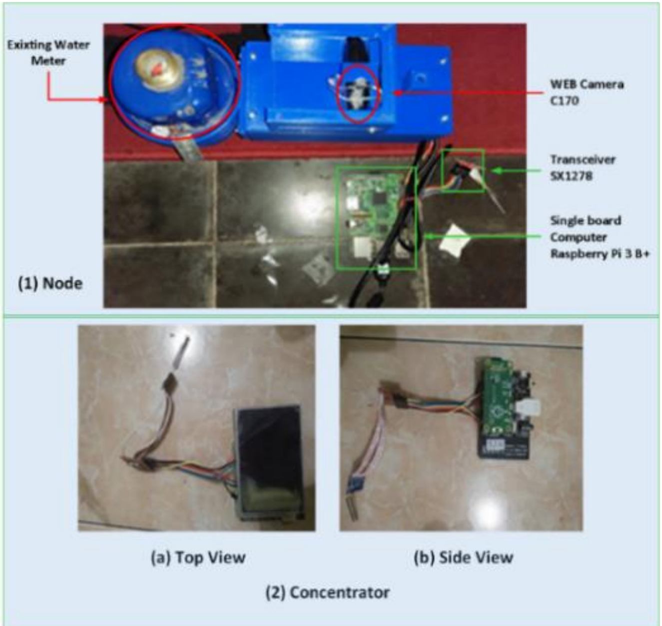
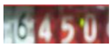
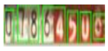


Figure 7. Centralized water meter reading system.

3.2. Testing and determining the focus distance of the camera

To ensure optimal camera focus at a certain distance to produce a very small conversion error, it is necessary to test and determine the value of the focus distance. The test is done by placing the camera and the object exactly vertically straight with a distance that changes every 1 cm, displays the results of the camera photo images and the software conclusions in detecting characters.

Table 6. The testing results of camera focus.

Camera distance	Image Detection Results	Character Detection Results
1 cm		No detected
2 cm		No detected
3 cm		Detected, Incorrect text
4 cm		Detected, Incorrect text
5 cm		Detected, Incorrect text
6 cm		Detected, Incorrect text
7 cm		Detected, Incorrect text
8 cm		Detected, Incorrect text
9 cm		Detected, Incorrect text
10 cm		Detected, Correct Text
11 cm		Detected, Correct Text
12 m		Detected, Correct Text
13 cm		Detected, Correct Text
14 cm		Detected, Correct Text
15 cm		Detected, Correct Text

The image was detected clearly at a focus distance of 3 cm but the software still concluded the shown number was "wrong", and the same result was up to a focus distance of 9 cm. But starting with a focal distance of 10 cm to 15 cm, the detection of the exact character is the same as the original on the water meter designation.

3.3. Accuracy in conversion of images into numeric text

The test results are in the form of text data loaded from Raspberry Pi MicroSD memory, as follows:

- Number of tests: 150 times
- Right Conversion Result: 121 times
- Incorrect Conversion Result: 29 times
- Accuracy of Reading: 81%

The success of the conversion depends on the quality of the image lighting. When the image receives a lot of light it will cause a line of reflected light that can be detected as a character even though it has gone through a pre-processing process to eliminate noise as in figure 8 below.

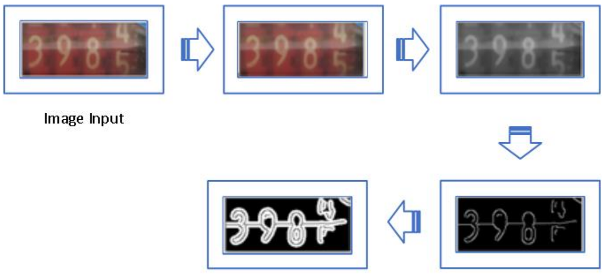


Figure 8. Reflected light detected as a character.

3.4. Communication distance between Node and Concentrator

The test is carried out by adjusting the position between the Node and the Concentrator with a straight distance that changes is started from 10 meters to 200 meters with a space of 10 meters, for three output power levels namely 5 dBm, 10 dBm, and 20 dBm.

Table 7. The test results of node and concentrator communication distance.

Distance (m)	**Received power (dBm) [sensitivity -111 dBm to -148 dBm]**		
	Pout = 5 dBm	**Pout = 10 dBm**	**Pout = 20 dBm**
1	-95	-89	-109
10	-94	-96	-111
20	-101	-101	-107
30	-101	-113	-122
40	-	-111	-122
50	-	-122	-124
60	-	-124	-123
70	-	-127	-127
80	-	-129	-125
90	-	-130	-125
100	-	-	-127
110	-	-	-128
120	-	-	-127
130	-	-	-128
140	-	-	-127
150	-	-	-128
160	-	-	-127
170	-	-	-128
180	-	-	-127
190	-	-	-128
200	-	-	-128

Based on the measurement data above, for a transmit power of 20 dBm the maximum distance that can be achieved is 200 meters.

4. Conclusion

Analog postpaid water meter reading system, using a C170 Webcam type camera for taking pictures shown the existing water meter with the selected focus distance is 10 cm straight vertically. And using Raspberry Pi 3 B+ as a control system in each sub-section of the device. For transmitting data from Node and Concentrator devices using a Wireless Transceiver type SX1278 with a selected transmit power of 20 dBm, and for telemetry data from the Concentrator to the central server using a cellular network. Conversion of images from the shown existing customer water meters into text data using OCR tesseract written using the Python programming language has a conversion accuracy value of up to 81%. The text data communication system results from the appointment of customer water meters from the node to the concentrator using a 433 MHz wireless transceiver, with the maximum distance that can be reached up to a radius of 200 meters. Data transmission is performed at the request of the concentrator to several nodes which are his responsibility in turn and sequentially based on the Node code that has been written on the concentrator database. While the communication made between the concentrator and the central server uses an internet-based cellular network.

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