

# Design a 4-Sided Proximity Sensor on a Car Using Ultrasonic

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**Abstract**— Driving safety is a primary emphasis of current vehicle technology research, particularly in transport vehicles with blind spots on all four sides. This research aims to design and implement a wireless sensor network-based safe driving distance measuring system using ultrasonic sensors integrated with the nRF24L01 wireless communication module. This system will be placed on four sides of the vehicle, namely front, rear, left, and right to monitor the distance to objects around the car in real time. After then, the measurement data will be shown on the LCD mounted on the vehicle's dashboard, making it simple for the driver to understand the notifications. The research method includes hardware design, Arduino microcontroller programming, and a series of tests in static and dynamic conditions. The test results show that the ultrasonic sensor has good accuracy, both in static and dynamic conditions, although there is a possibility of delay arising from external factors such as vehicle vibrations, uneven roads, and so on. The nRF24L01 module is able to transmit data with a fairly good success rate under conditions of non-stop synchronization from four different sides. The monitoring results can be used by the driver to make decisions regarding safe driving distance.

**Keywords**— Distance detection, microcontroller, nRF24L01, proximity sensor, ultrasonic sensor, vehicle blindspot.

## I. INTRODUCTION

Driving is one of the most prevalent daily activities in modern society, encompassing the operation of motorcycles, automobiles, trucks, and various other motorized vehicles. The rapid growth of motorized vehicle populations worldwide has become a significant concern, particularly in developing countries where infrastructure development has not kept pace with the increasing number of vehicles on the road. This imbalance has contributed to a persistently high rate of traffic accidents, resulting in substantial human casualties and considerable socio-economic losses that place a heavy burden on national resources and public welfare. Consequently, road safety has become an increasingly critical area of focus for researchers, policymakers, and engineers alike, driving the need for innovative technological solutions capable of mitigating accident risks in diverse and complex traffic environments.

One of the most persistent contributing factors to these accidents is the driver's limited field of vision in blind-spot areas [1], [2], which predominantly occur at the rear, left, and right sides of a vehicle. In specific operational contexts — particularly when navigating narrow lanes or congested road segments — the frontal zone may also become a functional blind spot. This issue is especially critical for medium-sized public passenger vehicles (angkot), which are widely operated across rural areas, rural-urban transition zones, and older urban districts throughout Indonesia. Drivers have commonly attempted to compensate through conventional measures such as installing additional mirrors or attaching rubber bumpers; however, these solutions demonstrate restricted effectiveness, offering marginal benefit only in near-stationary conditions

and providing little protection during dynamic driving scenarios.

Prior research has proposed various driving safety solutions, yet significant limitations persist. Many earlier systems were evaluated exclusively in controlled, flat-terrain environments that inadequately reflect real-world conditions [3], [4], [5], [6], [7], [8], while most designs lacked sufficient consideration of dynamic external factors such as surrounding moving vehicles. Additionally, existing prototypes [9], [10], [11], [12], [13], [14] demonstrated inadequate response adaptability across varying vehicle speeds, limiting their practical utility in real traffic situations.

In response to these challenges, this study proposes the design and empirical testing of a real-time vehicle safe-distance monitoring system based on a Wireless Sensor Network (WSN) architecture [11], [15], [16]. The system provides continuous, simultaneous distance measurements from four directions — front, rear, right, and left — using HC-SR04 ultrasonic sensors as the primary measuring transducers. Wireless communication between sensor nodes is facilitated by nRF24L01 transceiver modules, while an Arduino Uno microcontroller aggregates the sensor data and renders output on a dashboard-mounted LCD display for immediate driver reference.

This research addresses three principal objectives: evaluating the effectiveness of simultaneous data synchronization across all sensor nodes during active vehicle operation; comparing distance measurement responses from all four sides under dynamic driving conditions; and analyzing system response to inter-sensor measurement discrepancies and their implications for driver decision-making. The primary

measurement parameters are object distance in centimeters (cm) and transmission timing in seconds (s), with a maximum detection threshold of 400 cm established in accordance with HC-SR04 sensor specifications — values exceeding this limit are classified as out-of-range readings. The findings of this study are expected to contribute to the fields of embedded systems design, vehicular safety technology, and WSN applications, offering a practical and deployable framework adaptable to a broad range of vehicle types and road environments.

## II. METHOD

The research methods carried out in this journal are as follows:

### A. Related Study

Object detection research has been extensively pursued across a wide range of applications, with one prominent area of focus being the detection of motorized vehicles in the context of parking space analysis [17], [18], [19], [20], [21]. From an alternative perspective, object detection has also been approached as a means of measuring the spatial distance between a moving object and a stationary reference point.

A separate body of literature has addressed the blind spot challenges encountered by drivers [22], [23], [24], [25] — not only during parking maneuvers but also during active driving conditions — though such investigations have predominantly been confined to small passenger vehicles with a four-passenger capacity.

Several independent studies [3], [26], [27], [28] have employed simulation-based methodologies for low-cost object detection using standard family passenger vehicles. Nevertheless, these simulations frequently failed to produce satisfactory outcomes, largely due to the test vehicle traveling in parallel with the target object, which resulted in stable and minimally varying simulation data.

Related studies [4], [29], [30], [31], [32] adopted comparable approaches; however, their applicability remained constrained, as the methods were optimized for slow-moving objects, high-end vehicles, or platforms that were purpose-built from the outset, such as electric vehicles.

Following a comprehensive review and critical evaluation of the existing literature, the researchers identified the HC-SR04 ultrasonic sensor as a promising candidate for distance detection, owing to its relatively low cost and ease of implementation. In addition, the nRF24L01 transceiver module was incorporated into the proposed system as the primary wireless communication medium.

### B. Design of Prototype

The following is design and placement of prototype for proximity sensor :

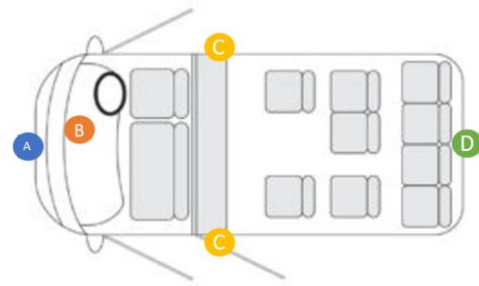


Figure 1. Proximity sensor placement

Figure 1 shows a miniature vehicle plan consisting of four areas; the front side, left and right side, rear side and inside of the vehicle (driver side). The following are the sensor descriptions:

#### 1. Front side (A)

This section measures in centimeters the distance between the car and another vehicle from the front side of the car.

#### 2. Inside / driver side (B)

This section receives data from the sensor nodes and displays the results in visual data via LCD.

#### 3. Left and right side (C)

This section measures in centimeters the distance between the car and another vehicle from the left and right sides of the car.

#### 4. Rear side (D)

This section measures in centimeters the distance between the car and another vehicle from the rear side of the car

### C. Operating System Flow Diagram

The following is operating system flow diagram :

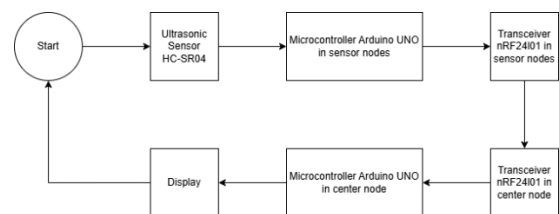


Figure 2. Process of looping dataflow

Figure 2 shows the process flow of transmitting commands to the sensor node device, from the ultrasonic sensor's reading of the distance data to the Arduino Node's processing of that data. The Arduino Node then uses transceiver nRF2401 to transmit data to Arduino Center. The distance data is then shown to the LCD via the Arduino Center.

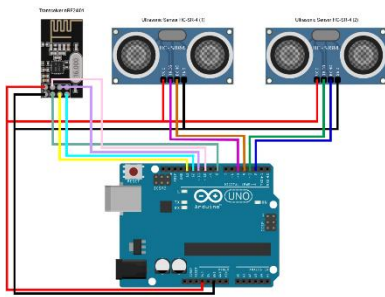


Figure 3. Block diagram in the transmitter section (Sensor Node)

Figure 3 shows two ultrasonic sensors and one transmitter. A car that drives faster than the test vehicle is anticipated by the two ultrasonic sensors. It is still possible for one of the sensors to record the return signal and produce data for the microcontroller. The transmitter system in this instance is referred to as the Sensor Node.

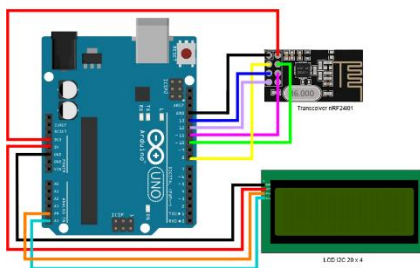


Figure 4. Block diagram in the receiver section (Center Node)

Figure 4 shows a receiver system with a monitor. This system is the main node that is mounted on the dashboard to give the driver distance information while driving. This system is referred to as the Center Node.

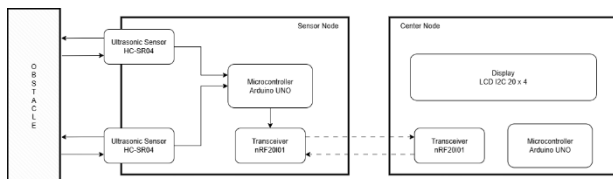


Figure 5. Proximity sensor block diagram

In Figure 5, shows the processes occurring at all nodes and the communication direction between Sensor Nodes and Center Node.



(D)

(E)

Figure 6. Proximity sensor placement in vehicle : front side (A), left side (B), right side (C), rear side (D) and driver side (receiver / Center Node) (E)

Figure 6 shows sensor node placements on the parts of the car. The center node displays distance measurement data in real time while driving. The displayed data is sorted from the front, left, right, and rear nodes data in one view. Testing was conducted on public roads without using alternative routes.

### III. RESULTS AND DISCUSSION

The following is the test result data taken while the vehicle is moving. The moving position is compared to the fixed location. In order to verify and/or calibrate whether the tool can detect at a specific distance, the tool is given a manual barrier with a specified distance, namely multiples of 50 cm; multiples are calculated up to 400 cm.

The stationary position is the condition when the tool measurement is performed before the car moves (speed 0 km/h). This means that the distance that will appear on the monitor is the maximum distance specified in the program script, which is 400 cm or a value close to that number.

On the other hand, the moving position occurs when the vehicle travels for  $\pm$ half an hour on the road at a speed that complies with Indonesian traffic laws pertaining to four-wheeled vehicles, specifically between 30 and 40 km/h.

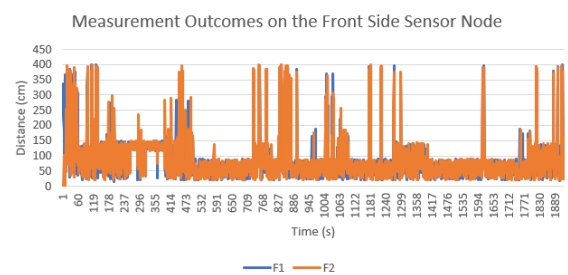


Figure 7. Proximity sensor data result on the Front Side Sensor Node

Figure 7 shows front sensor data displays frequent spikes reaching the 400 cm threshold, indicating intermittent signal loss or instances where no obstacles were within the detection range, interspersed with active detections at closer proximities

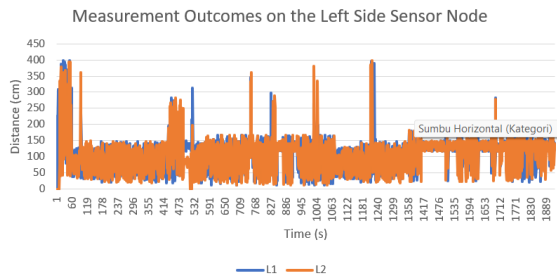


Figure 8. Proximity sensor data result on the Left Side Sensor Node

Figure 8 shows a steadier detection pattern on the left side sensor node, though it still exhibits several peaks at 400 cm, representing moments of 'out-of-range' conditions where the sensor failed to lock onto a specific object.

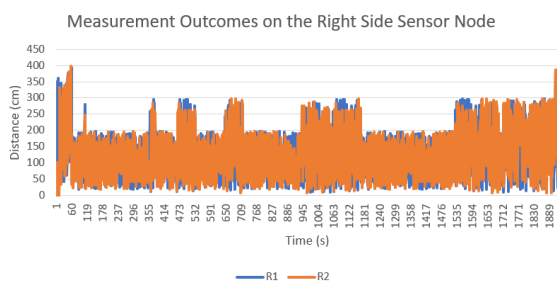


Figure 9. Proximity sensor data result on the Right Side Sensor Node

Figure 9 shows a dense cluster of readings below 300 cm on the right side node, with fewer instances of signal loss at the 400 cm mark compared to other nodes, suggesting a more consistent presence of objects on the right side

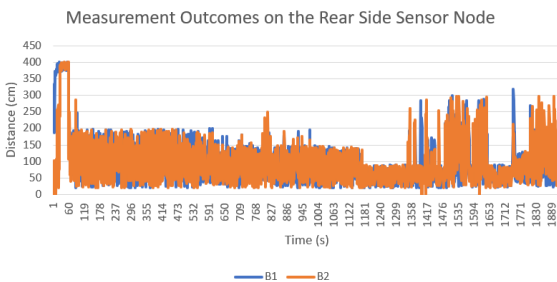


Figure 10. Proximity sensor data result on the Rear Side Sensor Node

Figure 10 shows unlike the other three sensors, the rear sensor only exhibited signal loss (approaching the 400 cm error threshold) during the initial seconds of the test. Following this, the values decreased and stabilized around 200 cm until the 611s mark. Throughout the middle to late stages of the test, the distance fluctuated between 100 cm and 250 cm, with a significant drop to 100 cm starting from the 1160s mark. This suggests that vehicles trailing behind the test car tended to maintain a relatively safe and consistent distance throughout the experiment.

To obtain a more comprehensive understanding of sensor performance throughout the entire test duration (1,800 seconds), the distance measurement data were classified into

time-interval segments of five minutes (300 seconds) each. This segmentation approach was adopted to minimise data noise and to facilitate observation of sensor stability under varying traffic conditions encountered at each phase of the journey. The interval-based analysis enables the identification of more specific detection patterns, including the monitoring of sensor accuracy transitions as the vehicle shifts from static to dynamic conditions, as well as during fluctuations in traffic density. The following section presents a detailed account of the distance measurement results for each time segment recorded throughout the testing process.

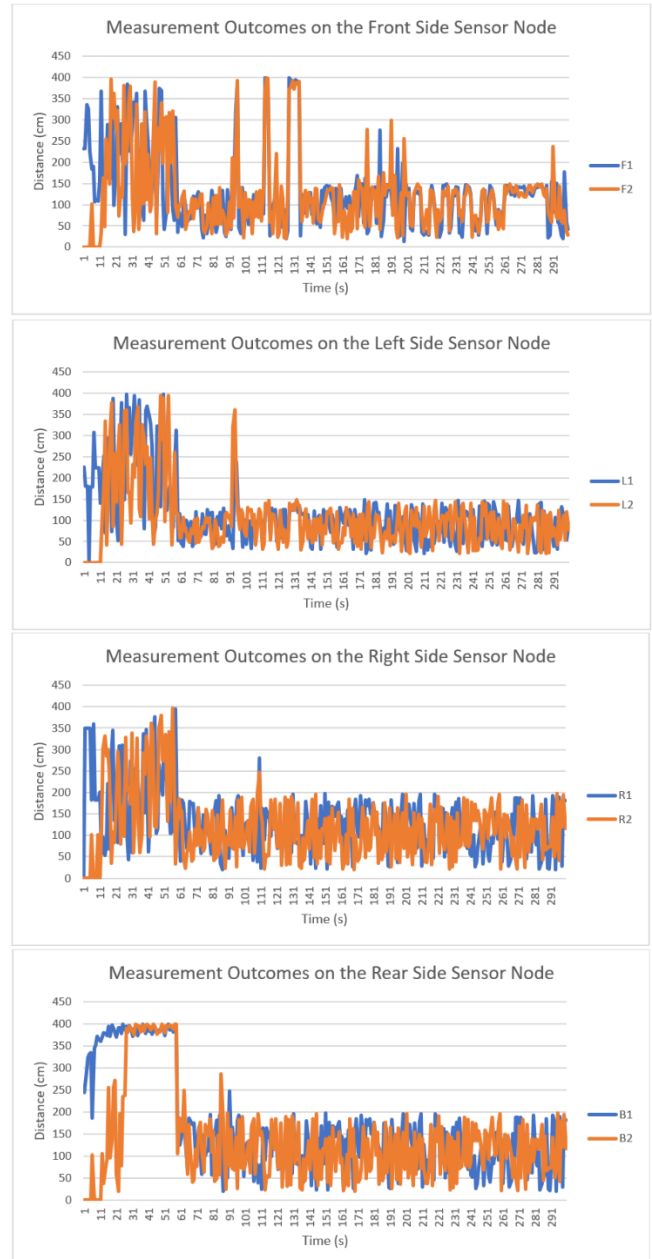


Figure 11. Measurement results in the initial phase on each sensor

During the initial phase of testing, spanning the first 300 seconds, Figure 11 shows that all four sensors exhibited

dynamic response characteristics relative to the surrounding environment. The front-side sensor displayed extreme and erratic value fluctuations, with frequent spikes reaching the error threshold of 400 cm, indicating detection instability in the forward zone of the vehicle at the onset of the journey. In contrast, the left- and right-side sensors demonstrated a considerably faster stabilisation pattern; within the first 60 seconds, both sensors successfully locked onto object distances within the 50 cm to 150 cm range, with noticeably more controlled fluctuations. The rear-side sensor produced the most distinct pattern of the four, whereby following the initial 60-second period, the system exhibited a high degree of measurement consistency within the 50 cm to 200 cm range, with no significant error interference recorded. Taken together, the findings from this first five-minute phase confirm that the system requires an adaptation period of approximately 60 seconds before achieving measurement stability, after which the sensors are capable of delivering reliable distance data to the driver.

Entering the second phase of testing (seconds 301–600), Figure 12 shows that the detection characteristics across all four sensors exhibited increasingly varied responses to changing conditions in the vehicle's surroundings.

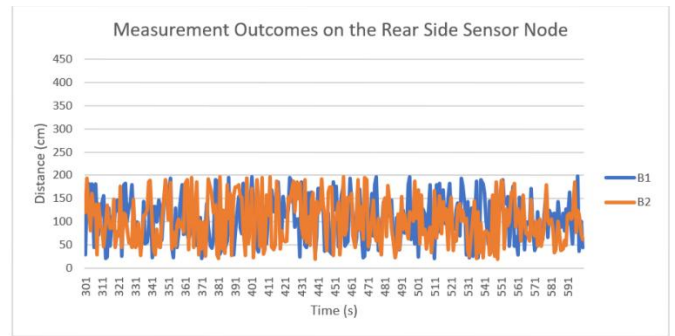
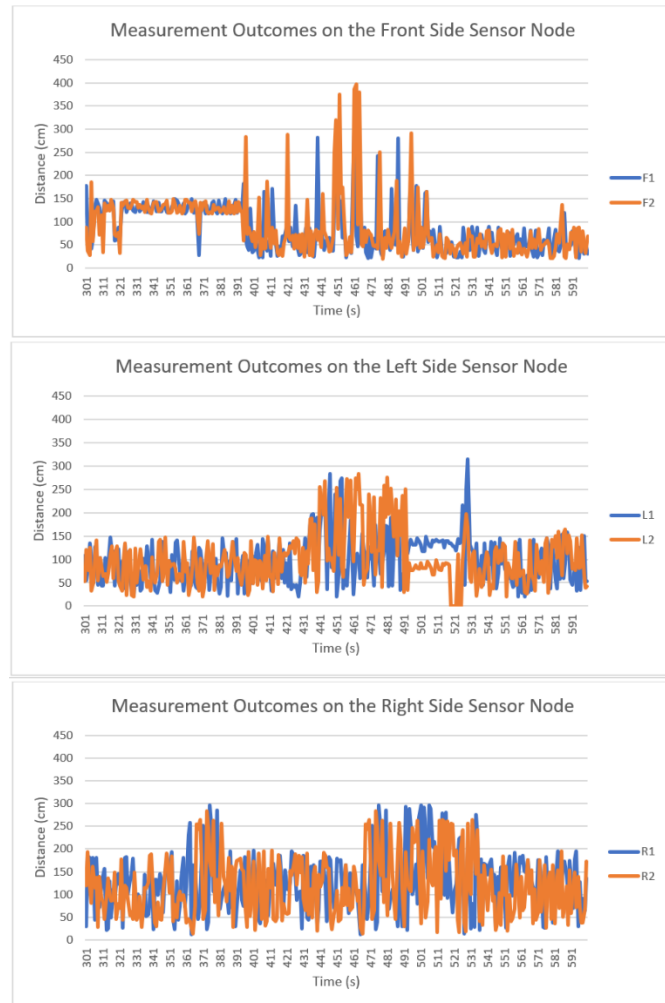
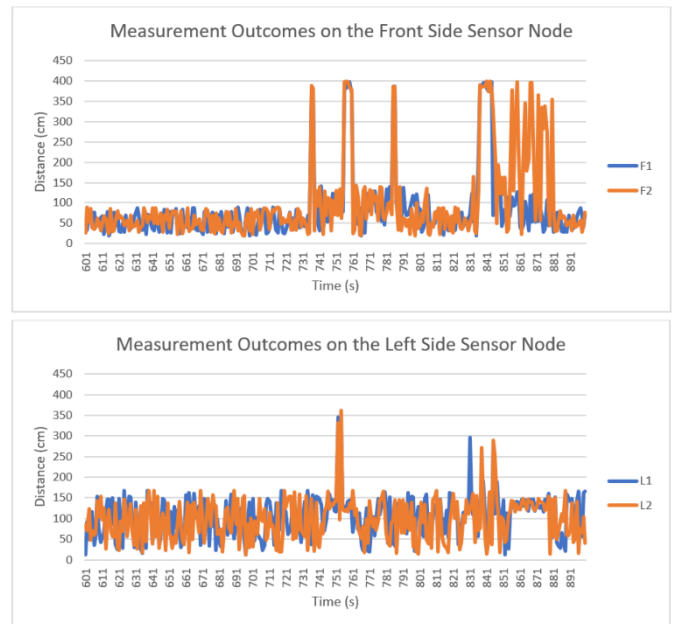
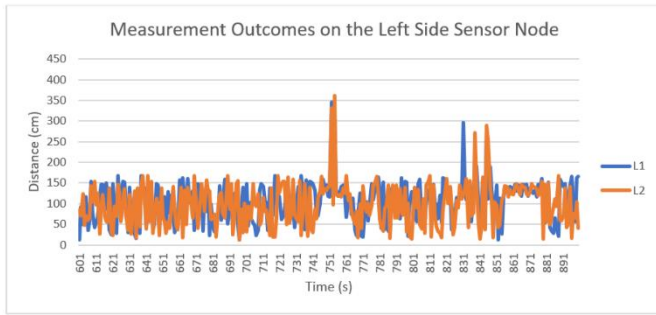


Figure 12. Measurement results in the second phase on each sensor

The front-side sensor once again displayed an unstable pattern, with sharp spikes reaching 400 cm between approximately the 440th and 490th seconds, reflecting the inconsistent detection of an obstruction or blind spot within that interval. Meanwhile, the left- and right-side sensors showed a marked increase in detection activity during the same period, with pronounced spike patterns in the 250–300 cm range, indicative of objects passing alongside the vehicle. The rear-side sensor, by contrast, maintained consistently strong performance throughout the entirety of the second phase, with distance value fluctuations distributed evenly within the 50 cm to 200 cm range and no notable anomalies recorded. This phase confirms that, as the test progressed, the left-, right-, and rear-side sensors were capable of sustaining data reliability, while the front-side sensor continued to represent the point of greatest susceptibility to signal fluctuation and interference.



(a)



(b)

Figure 13. (a)(b) Measurement results in the third phase on each sensor

During the third phase of testing (seconds 601–900), Figure 13 shows that the data patterns reflected noticeably varied traffic conditions in the vicinity of the test vehicle. The front-side sensor once again exhibited significant instability, particularly between the 730th and 880th seconds, during which the frequency of spikes reaching 400 cm increased considerably compared to the preceding phase. This phenomenon suggests the presence of obstructions or environmental conditions that caused the front-side sensor to repeatedly lose its detection target. The left- and right-side sensors, by contrast, demonstrated improved stability throughout this phase, although a brief spike was recorded on the left-side sensor at approximately the 750th second. The rear-side sensor continued to perform as the most consistent component in delivering distance data, with fluctuations maintained evenly within the 25 cm to 150 cm range. On the whole, the third phase reinforces the finding that the front-side sensor carries a higher degree of vulnerability to signal interference under certain road conditions, whereas the remaining sensors sustained a considerably more stable measurement continuity, thereby supporting the driver's need for reliable proximity information.

During the fourth phase of testing (seconds 901–1200), Figure 14 shows that the front-side sensor once again exhibited an intermittent pattern, with spikes to 400 cm recorded at approximately the 1,010th and 1,180th seconds, indicating brief lapses in object detection within the forward zone of the vehicle. Notably, during the intervals between these spikes, the front-side sensor demonstrated comparatively stable performance, with readings consistently falling below 100 cm. The left- and right-side sensors, meanwhile, displayed a markedly high level of detection stability throughout this phase; the left-side sensor recorded a consistent pattern within the 50–150 cm range with minimal anomalies, while the right-side sensor produced a tighter data distribution across the 50–250 cm range.

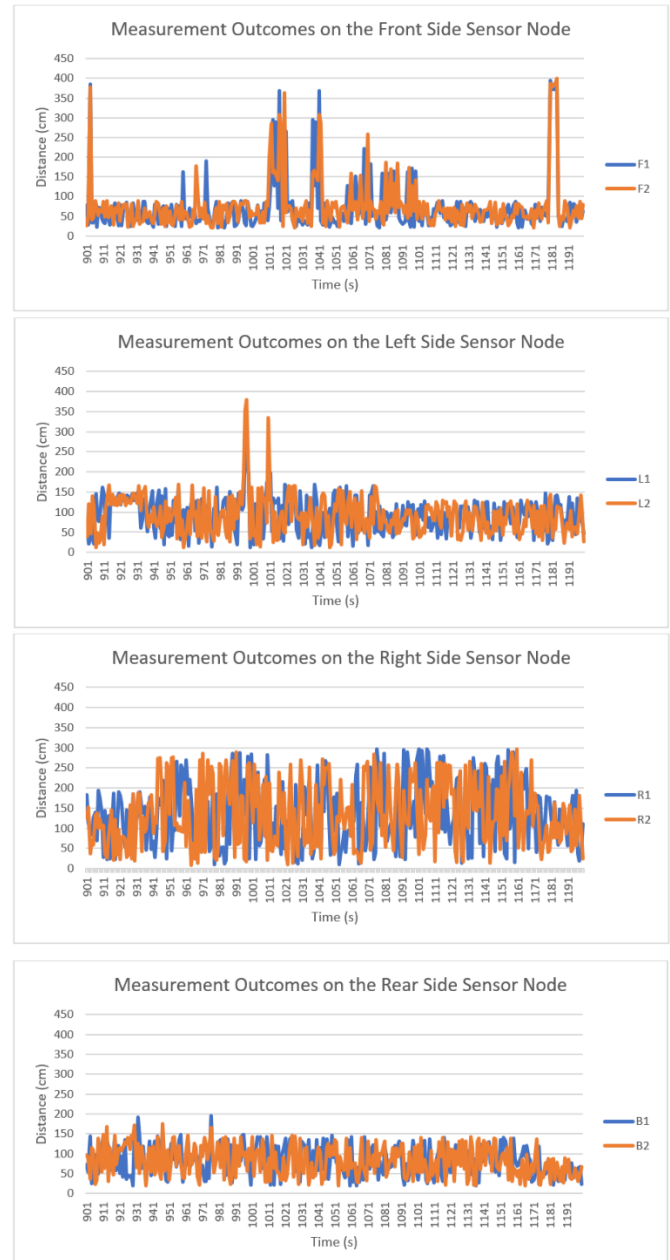


Figure 14. Measurement results in the fourth phase on each sensor

The rear-side sensor continued to uphold its strongest performance, with fluctuations maintained evenly within the 25–150 cm range throughout the phase. On the whole, the fourth phase demonstrates that the lateral and rear sensors had reached a state of optimal operational stability, whereas the front-side sensor remains in need of more refined data filtering to minimise false error occurrences under particular traffic conditions.

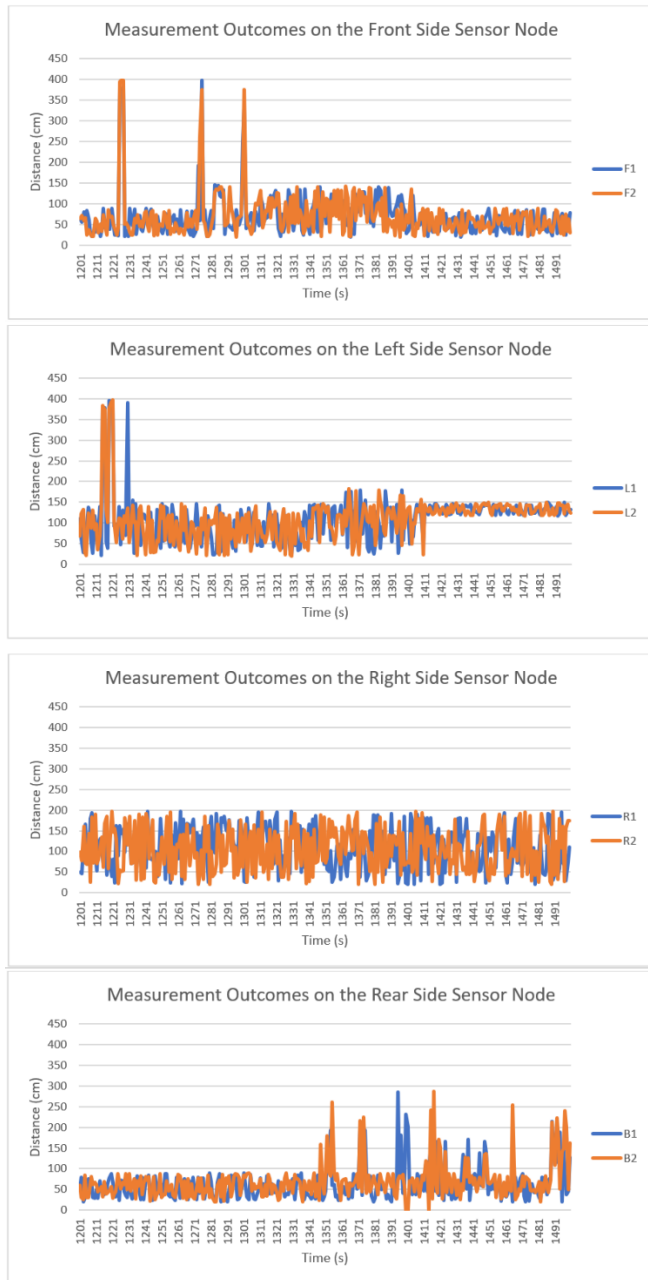


Figure 15. Measurement results in the fifth phase on each sensor.

During the fifth phase of testing (seconds 1,201–1,500), Figure 15 shows that the detection characteristics displayed a notably more mature pattern in comparison to the preceding phases. The front-side sensor still recorded occasional anomalies at approximately the 1,220th and 1,270th seconds; however, beyond those isolated instances, the system was capable of delivering considerably more stable distance readings consistently below 100 cm. The left-side sensor exhibited a significant shift in pattern, with a remarkable degree of stability emerging toward the latter part of the phase; from the 1,410th second through to the 1,500th, readings became highly constant at approximately 125 cm, signifying that the environment along the left side of the vehicle had entered a largely static condition. The right-side sensor

maintained consistent fluctuations within the 25–200 cm range, while the rear-side sensor began to show increased detection activity, with several spikes trending toward 250 cm following the 1,350th second. Taken together, this phase provides compelling evidence that over the course of an extended testing duration, the WSN system is capable of adapting and attaining an optimal level of measurement stability, particularly among the lateral sensors, which by this stage were delivering increasingly reliable data to support the driver in monitoring objects within blind spot zones.

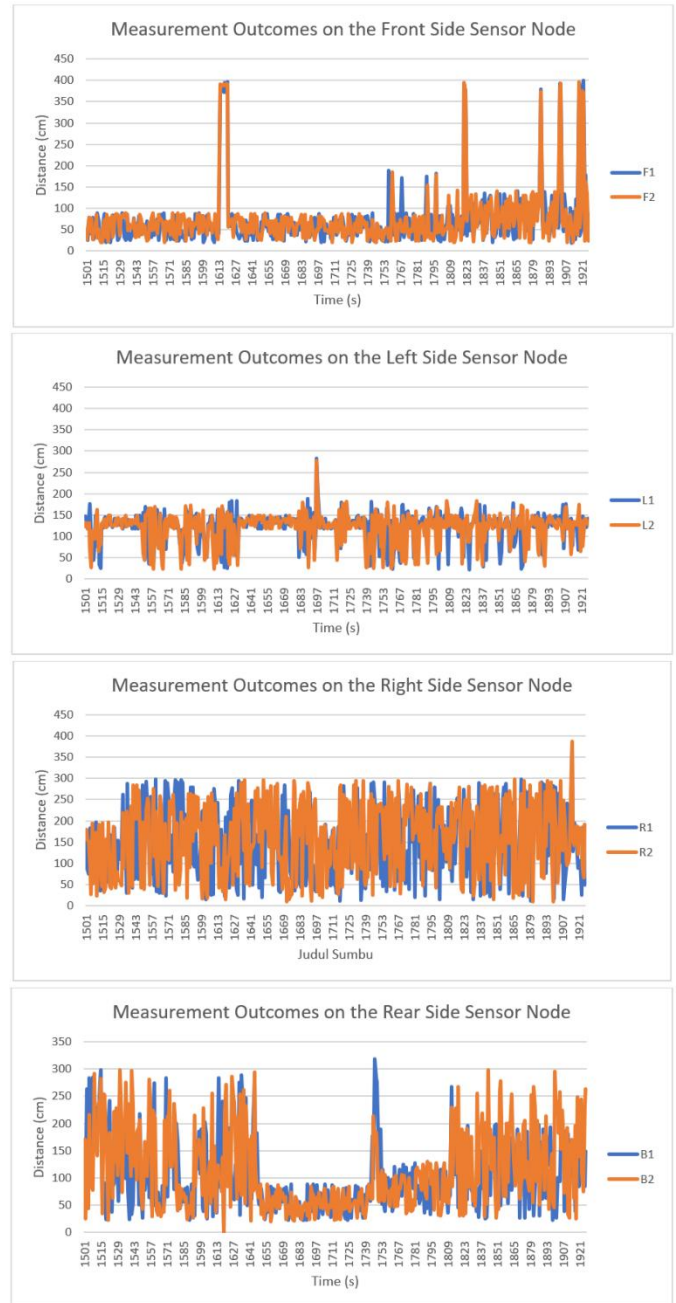


Figure 16. Measurement results in the final phase on each sensor

Entering the final phase of testing (seconds 1,501–1,921), Figure 16 shows that the sensor system displayed

characteristics reflective of the concluding stage of the vehicle's operational cycle. The front-side sensor still recorded occasional anomalies at the 1,610th and 1,890th seconds; however, beyond those isolated points, the sensor was capable of presenting distance data below 100 cm with reasonably maintained consistency. The left- and right-side sensors demonstrated stable fluctuation patterns throughout this phase; the left-side sensor sustained a detection range of 50–150 cm, while the right-side sensor exhibited a broader range of detection variation between 50–250 cm. The rear-side sensor offered a particularly noteworthy observation during this phase, wherein a period of relative inactivity was recorded between the 1,640th and 1,740th seconds, characterised by very low detection readings of approximately 50 cm, before resuming active operation with fluctuations rising toward 250 cm toward the close of the test. This sixth and final phase affirms that the WSN system as a whole remained fully functional throughout the maximum testing duration, demonstrating the capacity to capture shifts in environmental dynamics both as the vehicle decelerated and during conditions of increasingly sparse traffic density.

#### IV. CONCLUSION

Based on the results obtained from the testing of the Wireless Sensor Network (WSN) system developed for proximity sensor, it can be concluded that the proposed device demonstrates a capability for real-time data synchronization with an overall accuracy rate of up to 75%. Sector-based analysis reveals that both the left and right node sensors exhibited high operational stability within the detection range of 100 cm to 200 cm, accompanied by a minimal frequency of erroneous readings. In contrast, the rear node sensor demonstrated stable performance within the 200 cm to 300 cm range, albeit following an initial phase of measurement fluctuation. The front node sensor, however, recorded the most pronounced accuracy limitations, registering 12 instances of anomalous readings at distances of 400 cm or greater over a continuous 10-minute interval — particularly concentrated between the 700th and 1,282nd seconds of operation — thereby compelling drivers to continue relying on personal driving intuition within that detection zone. Overall, the observed data patterns indicate a higher vehicular traffic intensity on the left lateral side relative to the right, as well as a general tendency for trailing vehicles to maintain a consistent safe following distance. In consideration of these findings, future work should prioritize the optimization of data filtering algorithms or the introduction of sensor redundancy on the front side, in order to establish a more comprehensive and reliable safe-distance detection system — ultimately contributing to the mitigation of accident risks associated with limited driver visibility (blind spots).

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