An intelligent road accident reduction system using device-to-device communication

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ABSTRACT

Every year thousands of people are dying due to road accidents and most of the accidents are occurring in urban areas and highways. As the number of vehicles is increasing day by day, the probability of the occurrence of the accident is also increasing. A system has been introduced in this paper that can reduce road accidents by sending an alert to drivers via smartphones. For this purpose, an android-based application has been developed. To reduce the accident, every driver of the car must have the application. Firstly, the location of the vehicle will be collected from the driver's smartphone, then the data will be sent to the server through the application. An algorithm has been also developed using Haversine Formula which calculates the distance among the vehicles. A total of five cases have been implemented according to the dataset and compared for the performance evaluation. An extensive experimental study and comparison have been performed with the other methods where a complete performance is focused that can be claimed to reduce road accidents via the device-to-device communication process.

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1. INTRODUCTION

Road accident has become a common incident nowadays all over the world. Thousands of people die every year due to road accidents. Over-speed, driving while drinking, usage of defective vehicles, reckless driving, break failures of vehicles, talking over the phone while driving, driving by unskilled drivers, and violation of traffic rules are the main causes of road accidents. Also, road accidents have become a very common phenomenon in a largely populated country like Bangladesh. The road accident fatality rate in this country is very high. A study by the Accident Research Institute (ARI) shows that on an average of 12,000 lives are taken away by road accidents in this country and almost 35,000 people get injured severely due to the road accidents annually [1]. In a study, it has been stated that more than 90 percent of world's road accident occurs in the low incoming and poor countries that cause more damage to those countries compared to the developing and developed ones [2]. We can clearly understand that the occurrence of these accidents is rising increasing the severity of the accident daily. The number of transportation, as well as the population of this country, is growing drastically and for that, the number of casualties from road accidents is rising too. Previously a few systems like ultrasonic sensors had been used to detect accidents [3]. Some researchers have works related to this type of study. In the paper from [4], a vehicle-to-vehicle communication system has been developed which can be used to optimize vehicle safety using a temperature sensor, humidity sensor, and proximity sensor. Gul [5] used the least-squared method and Kalman filters to estimate the instantaneous latitude, longitude, altitude, and velocity of a vehicle. Sampoornam *et al.* [6] proposed different types of sensors like tilt sensors, vibration sensors, and infrared (IR) sensors to detect road accidents. Depending on the nature of the vehicles, the system notifies the registered members whenever an accident takes place in paper [7]. Pathik *et al.* [8] have proposed an approach using the haversine formula for calculating the shortest distance between the two points of the earth. An internet of things (IoT) based kit has been developed that can detect accidents and can extract accident-related information. A comparative analysis has been done using residual neural network (ResNet) and InceptionResnetV2.

Mahariba *et al.* [9] proposed an automatic system of accident detection in vehicles like powered-two-wheelers such that motorbikes in real-time scenario. An intelligent model based on IoT devices that can predict as well as sense the pre-accident or pre-collision stage of any accident is proposed in paper [10]. Based on that prediction it creates an alarm message regarding the collision or accident to make the driver aware of that accident. This model can derive image and video features to detect an accident.

To get the longitude, latitude, speed, and acceleration of a vehicle, Mamun *et al.* [11] have developed an application that is IoT and android-based. Mamun *et al.* [11] used the k-means clustering method and analyzed two different algorithms to detect road inconsistency and accident-prone areas. The experimental results outperform in terms of the state-of-the-art methods [11].

A system has been proposed that utilizes stimulated data gathered from vehicular ad hoc networks (VANETs). It collects the speed and coordinates information of the vehicles and using that sends traffic alerts to the users. Some machine learning models have also been used to achieve the performance evaluation of the model where the random forest algorithm showed the highest accuracy of 91.56% in detecting accidents cite12. The implementation of IoT in intelligent transport systems has been discussed in [13].

When the drivers are unaware of the marked lanes and other vehicles, the accidents tend to occur more according to paper [14]. Piece-wise linear stretching functions (PLSF) and euclidean distance transform are the base of the algorithm that has been proposed in the study. After checking the location of the vehicles within the marked boundaries, the system sends a message to the drivers which is basically an awareness message of the surroundings.

A smart IoT-based accident detection and insurance claiming system (ISADICS) has been introduced and implemented to detect accidents as well as for claiming insurance. In this system, the built-in global positioning system (GPS) is connected to Raspberry Pi and a vibration system is enabled to alert the system about the accident to take necessary actions [15]. The required time of traffic accident investigation was reduced to 66% with the help of a device that was addressed as road traffic accident information system (RTAIS) by Tai *et al* [16]. Jahan *et al.* [17], a has implemented a "Blackbox" module that helps to map and record or document the data of a specific road's condition that can be compared with the available accident data of those locations and alert system is enabled for those accident-prone areas. By this approach, the rate of accidents each year can be reduced up to 80%. A real-time implementation of a testbed has been introduced that got 90% accuracy followed by an acceptable delay to recognize traffic systems for preventing road accidents using tensorflow and Raspberry Pi [18]. The existing problems and drawbacks of VANETs have been discussed in [19].

A particle swarm optimization with artificial neural network (PSO-ANN) approach has been introduced to measure traffic collision in the paper [20]. In paper from [21], for preventing accidents, the relative locations of the vehicles have been determined with the help of GPS and transferred the information of the location using GPS in the targeted devices. To reduce and prevent the number of accidents due to sleep, an artificial intelligence (AI) and IoT-based intelligent system have been proposed in the paper [22]. In our study, a real-time system has been developed to ensure the safety of the drivers and for the vehicular system to reduce damage.

2. PROPOSED MODEL

An intelligent system for reducing road accidents through device-to-device (D2D) communication has been discussed in the proposed model. This section has represented the structure of the system model, how it works, and the outcome of this approach. The methodology starts with real-time data collection from google map application programming interface (API). The system grants permission to use google services as well as the networks and services they are related to. Here Google API is used for sending and receiving data from device to device. Distance data is gained and stored with the help of google map API. Then the data is sent to the server via smartphones. When the data is sent to the server a unique Firebase cloud messaging token has been generated as shown in Figure 1.

The messages and the notifications of a web application for android and iOS are handled by Firebase also known as FCM which is very popular for being able to work on a cross-platform. The system offers very fast database access and back-end services. The system offers the developers the opportunity to work on an API that synchronizes the data across clients and keeps the application data saved in the cloud. A script runs in a live server and all kinds of calculations are done in that server. After that, the Firebase is used for sending the notification to the users as described in Figure 1.

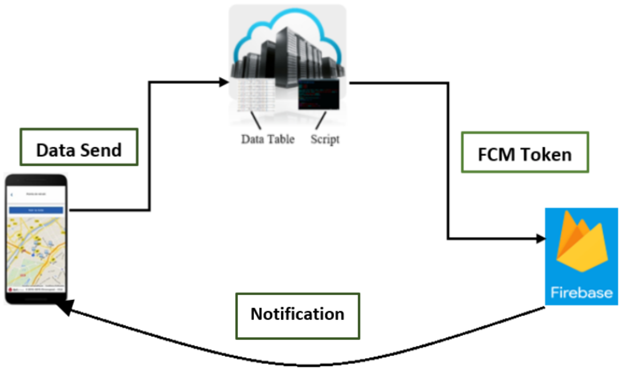

Figure 1. Notification system

2.1. Procedural flowchart

This section contains the procedural workflow of the proposed models. The proposed application's work initiates from smartphones. The device to device to connectivity will derive the location information and this will be kept updated on the server. The proposed model comprised of the steps such as calculations on the server, the application of the Haversine formula on distance calculations, proposed algorithms for accident detection, and distance finding which have been discussed in the following sections.

2.1.1. Data send to the server from smartphone

Data (latitude, longitude, speed, length, and FCM Token) is sent to the server from a smartphone. If the data can get access to the database of the server and gets stored successfully, there will be a positive pop-up message "Data Uploaded Successfully". Otherwise, there will be a negative pop-up message "Error, Data Not Uploaded" which has been depicted in Figure 2.

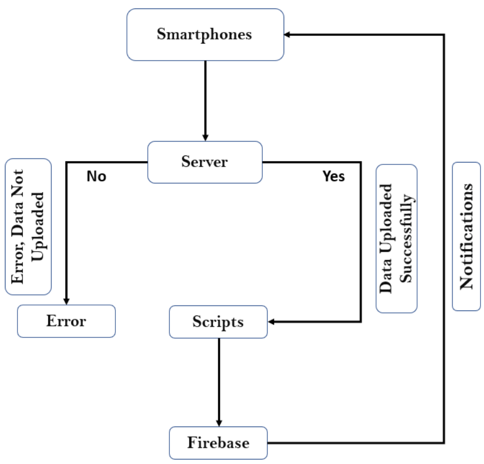

Figure 2. Flowchart of the application system

2.1.2. Calculation in server

Initially, the data is uploaded to server. After that, the proposed algorithm which has been used to run the system model has been discussed later. A notification will be sent to the devices through firebase which has been depicted in Figure 2.

2.1.3. Haversine formula

One of the most popular and effective formula that is used to calculate the distance between multiple locations is the haversine formula [23]. The formula gives us the orthodromic distance between two points which is basically a circle distance. When the latitude and the longitude of two locations have been given in the system then the Haversine formula can calculate the distance between those two points and can display the distance on the interface of our application. The maximum ranges of the longitude are 180 degree east and 180 degree west from the prime meridian. For any two locations on the earth the formula can be defined with the following (1)-(3) [24]. The symbol's meaning of the haversine formula is mentioned in the Table 1.

$$a = sin^2(\frac{\Delta\Phi}{2}) + cos\Phi 1 \times cos\Phi 2 + sin^2(\frac{\Delta\lambda}{2}) \tag{1}$$

$$c = 2 * atan2(\sqrt{a}, \sqrt(1-a)) \tag{2}$$

$$d = R \times c \tag{3}$$

Table 1. Symbol meaning of haversine formula

Symbol	Meaning
d	Distance between two locations
r	Radius of the orbit of $\Phi 1, \Phi 2$
$\Phi 1$	Latitude value of location^1
$\Phi 2$	Latitude value of location^2
$\lambda 1$	Longitude value of location^1
$\lambda 2$	Longitude value of location^2
c	Angular distance in radians
a	Square of half the chord length between the points

2.1.4. Proposed algorithm

For two algorithms have been proposed for our system. One of them is the distance finder algorithm which will measure the distance between the vehicles. The other one is the accident detection algorithm that will detect the occurance of any accident. Algorithm 1 distance finder algorithm: the value of latitude and longitude of two locations and the radius of the Earth has taken as the input of the distanceFinder() function.

Algorithm 1 Distance finder algorithm

$DistanceFinder(Latitude^1, Longitude^1, Latitude^2, Longitude^2)$
$r \leftarrow Earth\_radius$
$latitudeDistance \leftarrow deg2rad(latitude^2 - latitude^1)$
$longitudeDistance \leftarrow deg2rad(longitude^2 - longitude^1)$
$temp1 \leftarrow sin(latitude - distance/2) \times sin(latitude - distance/2)$
$temp2 \leftarrow sin(longitude - distance/2) \times sin(longitude - distance/2)$
$temp3 \leftarrow deg2rad(latitude1)$
$temp4 \leftarrow deg2rad(latitude2)$
$temp5 \leftarrow cos(temp3) \times cos(temp4)$
$a \leftarrow ((temp1)^2) + (temp3 \times temp4) \times ((temp2)^2)$
$c \leftarrow 2 \times asin(sqrt(a))$
$distance \leftarrow 2 \times r \times c$
return $distance$

Firstly, the latitude and longitude distance between two different locations has been calculated. Then the latitude and longitude values have been converted from degree to radian and are saved in temp3 and temp4. The cosine values of temp3 and temp4 for our calculation are calculated and saved in temp5. The sine values of the latitude and longitude of the two respective locations are kept in temp1 and temp2. From variables temp1, temp2, temp3, and temp4, we have calculated the value of a using (1). Then, the value of c has been taken by using the value of "a" into this equation 2 $\times$ asin(sqrt(a)). Finally, multiplying by the value of c with the radius of the earth, the distance between two locations has been calculated.

Algorithm 2 accident detection algorithm: the distance among the vehicles is calculated by placing the latitude and longitude of the location inside the distanceFinder function. A set of vehicles location (latitude, longitude) is used as input and the distance has been returned as an output of the algorithm. When the distance between two vehicles is less than the minimum threshold, then it detects it as an accident and provides a detection notification.

Algorithm 2 Accident detection algorithm

Require: $set\ of\ vehicles\ location$
Ensure: $Accident\ Notification$

for $all\ lac_i, loc_i \in set\ of\ vehicles\ location$ **do**
    for $all\ lac_j, loc_j \in set\ of\ vehicles\ location$ **do**
        $distance \leftarrow distanceFinder(lac_i, loc_i, lac_j, loc_j)$
    end for
end for
if $distance \leq minThreshold$ **then**
    Return $accidentDetected$
end if

2.1.5. Minimum threshold for accident occurrence

The smallest amount of notification has been found for the 3-meter distance between the vehicles after testing with a data set of approximately 2,340 tuples. When the minimum threshold was 8 meters, then 700 notifications have been determined from the calculation. In the same way, when the threshold values were 6, 4, 3, and 2, then 900, 500, 150, and 400 notifications have been found from the algorithm respectively. That's why 3 meters has been considered as the minimum threshold distance value between two or more vehicles for the accident that occurred which is depicted in the Table 2 also for the accident occurring threshold distance between two or more vehicles for the accident occurring which is depicted in the Table 2 also.

Table 2. Accident occurring threshold

Min threshold	Generated number of notification
8	700
6	900
4	500
3	150
2	400

2.1.6. Accident detection

Smartphones are placed beside the steering of cars, to collect the current positions of a vehicle. For calculating the distance between two or more vehicles, the real-time GPS location has been used. For collecting real-time location of the vehicle to locate road anomalies, the latitude and longitude are taken through the GPS of the smartphone. From the GPS sensor, the real-time distance has been calculated between vehicles to identify the location of the vehicles. Finally, alert messages will pop -up via notification to smartphones.

When the distance between the two vehicles is less than 3 meters drivers of that two vehicles will get a voice alert on their devices. From Figure 3, it is visible that the distance between two cars is less than 6 meters so the driver of the 2^{nd} car will get the notification "Be careful, slow down your car". So, the drivers of both cars will get the alert "Be careful, slow down your car".

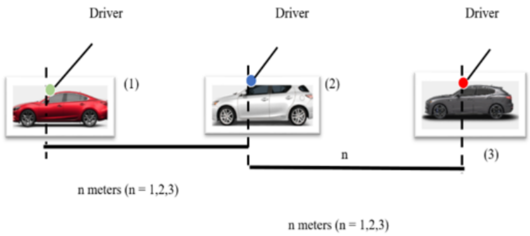

Figure 3. Accident detection

3. RESULT AND DISCUSSION

The performance evaluation of the proposed model has been done by comparing five cases. Depending on the number of notifications generated and the required parameters taken into consideration in the calculation, the cases have been compared. The cases followed by their limitation, how they differ from each other, and how a case is better than the previous one is discussed in this section and thus the best case is evaluated.

3.1. Case 01: (latitude, longitude, FcmToken and time)

First, the value of latitude and longitude have been taken by using GPS from devices. By using our algorithms, the distance between the two devices is measured and the notification has been sent. Here, the measurement of the distance between two devices has been done according to the server time, not depending on the device's time. For this condition, the threshold has been taken 3 meters to detect an accident that is when two vehicles are within 3 meters, then the drivers will be notified for safe driving. However, when only the latitude and longitude conditions are taken then, the driver gets a lot of notifications because so huge traffic is sent to the server. So, it may be confusing for the drivers to take appropriate decisions. The data for case 01 such as latitude, longitude, FcmToken, and time is depicted in Table 3. Limitation: when vehicles come in the range of 3 meters around the car, then the driver will get a notification. On a busy road, it can be very confusing as the drivers will get a lot of notifications continuously.

Table 3. Data set for case 01

ID	Latitude	Longitude	FcmToken	Time (pm)
01	23.7667186	90.4284154	ebfBZ2JQpuoAPA91bFBY..	4.24
02	23.7667468	90.4284144	ebfBZ2JQpuoAPA91bFBY..	4.24
03	23.7667531	90.4284265	ebfBZ2JQpuoAPA91bFBY..	4.24
04	23.7636675	90.4252027	qwJDXGeiAGAAP1b1Zchs..	4.25
05	23.7636645	90.425186	qwJDXGeiAGAAP1b1Zchs..	4.25
06	23.7667368	90.4284208	ebfBZ2JQpuoAPA91bFBY..	4.25

3.2. Case 02: (latitude, longitude, length, FcmToken and time)

In this case, according to the server time, the distance has been calculated between two devices and the length of the vehicles. Considering the length of the vehicles, different distance is found because there are several types of vehicles on the road and their length differs from each other (like the standard size of car 5 meters and truck 19 meters). From Figure 4, the car driver will get a notification when the distance from the truck within the 24 meters to the car. Besides, the truck driver will get a notification when the distance from the car to the truck will 8 meters. The data for case 02 such as latitude, longitude, FcmToken, length and time is depicted in Table 4. In this case, it also generates so many notifications when vehicles are within 4 meters as like case 01. Limitation: as many vehicles are in range, so the vehicles of the drivers get lots of notifications and they become confused as well as case 01.

Table 4. Data set for case 02

ID	Latitude	Longitude	FcmToken	Length (m)	Time (pm)
01	23.9667026	90.4344154	c-bfBZ2JQpu2391bF54BY6..	19	5.05
02	23.9667168	90.4344054	c-bfBZ2JQpu2391bF54BY6..	19	5.05
03	23.8567531	90.3584265	f-bfBcv2JQpuoAPA91bFBY..	5	5.06
04	23.8567031	90.3580065	f-bfBcv2JQpuoAPA91bFBY..	5	5.06
05	23.7636645	90.7251861	xqw34JDXGeiAGAAP1b1Zchs..	7	5.07
06	23.7660068	90.6284208	tybfBcv2JQpuoAPA91bFBY..	9	5.09

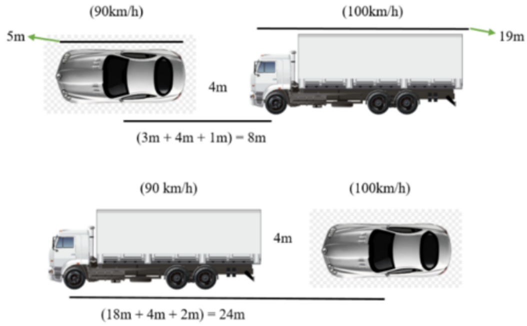

Figure 4. Length speed detection

3.3. Case 03: (latitude, longitude, speed, FcmToken and time)

In this section, vehicle speed has been taken and distance is calculated between two devices according to the server time. In case 03, another attribute named speed is added to overcome the limitations of case 01 and case 02. Corresponding data for case 03 such as latitude, longitude, FcmToken, speed, and time is depicted in Table 5. Basically, this case considers the speed of the vehicle and finds out the distance of different vehicles to send notifications. Finally, vehicles will be notified when they are within a certain range. Limitation: fewer notifications are generated in this case compared to earlier ones, which means that the drivers will receive fewer alerts.

Table 5. Data set for case 03

ID	Latitude	Longitude	FcmToken	Speed (Km/h)	Time (am)
01	23.8667026	90.4144154	lkjfCV2JQpu591bg53Y6..	1	10.05
02	23.8667168	90.4144054	lkjfCV2JQpu591bg53Y6..	2	10.05
03	23.8667668	90.3184265	lkjfCV2JQpu591bg53Y6..	3	10.06
04	23.7936145	90.3780065	bfBcv2JQpuoAPA91bFBY..	1	10.06
05	23.7936645	90.3780565	bfBcv2JQpuoAPA91bFBY..	5	10.07

3.4. Case 04: (latitude, longitude, speed, length, FcmToken and time)

In this case, the length and speed of the vehicle are taken for the calculation. Condition-1: vehicle's current speed is greater than the previous speed and within range of threshold limit (minimum Threshold). Condition-2: vehicle's current speed is less than previous speed and within range of threshold limit (minimum Threshold). Respective data for case 04 as latitude, longitude, FcmToken, speed, length, and time is depicted in Table 6. Here, both speed and length attributes are considered for calculation. If the current speed is greater than the previous speed and fulfilled condition-1, then that vehicle's driver will get a notification first. On the contrary, if the current speed is smaller than the previous speed and fulfilled condition-2, then that vehicle's driver will get a notification later. Thus, the driver gets a few numbers of notifications.

Table 6. Data set for case 04

ID	Latitude	Longitude	FcmToken	Speed (Km/h)	Length	Time (pm)
01	23.3667026	90.3194154	4tlkjfCJQpu591bg53Y6r..	19	1	12.05
02	23.3667168	90.3190154	4tlkjfCJQpu591bg53Y6r..	19	2	12.05
03	23.5367668	90.3384265	h-fBcv5JQpIoAcv91bcBY..	5	3	12.06
04	23.5367868	90.3384065	h-fBcv5JQpIoAcv91bcBY..	5	1	12.06
05	23.1936645	90.3780565	l-Bcv2JQpuoAPA91bFBY..	7	5	12.07

3.5. Case 05: (latitude, longitude, and FcmToken)

When users log in to the app, then the data will be sent to the server and stored in the database (previous data does not exist). Then, data will be kept updated until the user is logged out of the app. At first, one data will be inserted into the data table for one user. Then, the next upcoming data will be updated on the data table according to the users (if the user exit from the dataset, then upcoming data will update the previous one). Corresponding data for case 05 such as latitude, longitude, and FcmToken are depicted in Table 7. In this case, only the last data is taken from one device and calculated the data to send the notification. When users log out from the app, the data will automatically erase from the server and they will not get any alert. As a result, only one notification will send to the driver. Case-05 overcomes the limitations of the previous cases by reducing the number of notifications. In this case, only one notification has been sent to the user. Besides, the overtaking tendency among the drivers is not considered yet. But, overtaking tendency is a prevalent issue nowadays which is another cause of the occurrence of accidents. By alerting drivers when they are within the threshold limits, the intelligent accident detection system of our proposed approach aims to minimize the frequency of accidents. Our system will alert the user that there is a possibility of occurrence of an accident when any vehicle overtakes another. As a result, the likelihood of the occurrence of an accident will be decreased.

Table 7. Data set for case 05

ID	Latitude	Longitude	FcmToken
01	23.3667026	90.3194154	4tlkjfCJQpu591bg53Y6r132..
02	23.8667168	90.4144054	lkjfCV2JQpu591bg53Y6e3..
03	23.8567531	90.3584265	f-bfBcv2JQpuoAPA91bFBY..
04	23.5367868	90.3384065	h-fBcv5JQpIoAcv91bcBY2k..
05	23.1936645	90.3780565	l-Bcv2JQpuoAPA91bFBY12..
06	23.7660068	90.6284208	tybfBcv2JQpuoAPA91bFBY..

3.6. Comparison of the cases

The comparison among the above cases is shown in the Table 8. It is observable that Case 05 is better than any other case. This case has been considered better for generating the least number of notifications than all other cases.

Table 8. Comparison of cases

Attribute	Case 01	Case 02	Case 03	Case 04	Case 05
Latitude	Yes	Yes	Yes	Yes	Yes
Longitude	Yes	Yes	Yes	Yes	Yes
Length	No	Yes	No	Yes	No
Speed	No	No	Yes	Yes	No
Server Time	Yes	Yes	Yes	Yes	No
FcmToken	Yes	Yes	Yes	Yes	Yes
Notification	a lot of	a lot of	a few no. of	a few no. of	only one

3.7. Three users notifications

Usually, seven data is sent to the server per minute from one device. So, the total number of data ($3 \times 7 = 21$) is sent to the server within one minute. Here, if all of them (data) fulfilled the conditions and gave an alert to each other (user). When user 1 and user 2 fulfill the conditions, both will get an alert. Similarly, for user 1 and user 3, user 2 and user 3 will get an alert when they fulfill the conditions (Case 05). However, when user 1 sends an alert to user 2, then next time user 2 will not send an alert to user 1 because user 1 already sends an alert to user 2. In case 01, there are 21 notifications ($(21 \times 3)/3 = 21$) send to the three users within a minute. In case 02, it is 15 as there are 15 numbers of notifications generated. Similarly, in case 03, case 04, and case 05, the notification is 9, 6, and 3 respectively (from Table 9).

Table 9. Showing the number of notifications for 3 users

Cases	User 1	User 2	User 3	Notifications
Case 01	Yes	Yes	Yes	21
Case 02	Yes	Yes	Yes	15
Case 03	Yes	Yes	Yes	9
Case 04	Yes	Yes	Yes	6
Case 05	Yes	Yes	Yes	3

3.8. Two users notifications

Here, assume that user 1 and user 3 fulfill the condition and send alerts to each other. So, a total of 21 numbers of data will send to the server, but 14 numbers of data ($(21 \times 2)/3 = 14$) will fulfill the condition because user 2 does not fulfill the condition for case 01. Again, in case 2, there are 10 numbers of data that fulfill the condition according to case 02. Similarly, there are 6 for case 03, 4 for case 04, and 2 for case 05 respectively (from Table 10).

Table 10. Showing the number of notifications for 2 users.

Cases	User 1	User 2	User 3	Notifications
Case 01	Yes	No	Yes	14
Case 02	Yes	No	Yes	10
Case 03	Yes	No	Yes	6
Case 04	Yes	No	Yes	4
Case 05	Yes	No	Yes	2

4. COMPARISONS WITH STATE-OF-THE-ART-WORK

A comparative analysis has been shown in Table 11. It indicates the similarities and differences between the state-of-the-artwork with the proposed system to ensure safe driving. Our system proves its effectiveness in all conditions such as distance calculation (V2V), detecting accidents, detecting the nearest vehicles, and sending alerts.

Table 11. Comparing with state-of-the-art-work

References	Distance calculation (V2V)	Detecting accident	Detecting nearest nehicle	Sending alert
Proposed approch	Yes	Yes	Yes	Yes
DMSBIS [11]	Yes	Yes	Yes	No
TMSAAV [14]	No	Yes	No	No
SRDC [25]	Yes	No	Yes	No

5. CONCLUSION

Road accident is an unexpected incident in our daily life that happens in the blink of an eye and not only takes away people's lives but also leaves a bad impact on the growth of a country as well. In a developing country like ours, it has become a curse. But on the other hand, the number of population is increasing day by day and for that reason, the purchase and usage of vehicles are also increasing which increases the possibility of road accidents. Unfortunate events like accidents cannot be stopped but there are ways to decrease the impact of road accidents. In this paper, a developed model was proposed to reduce road accidents that ensures safe driving through an android-based application where every device will be connected to another device. In this system inputs (latitude, longitude, speed (vehicle), length (vehicle), time (server)) are acquired using Android based applications that have the capability of real-time implementation. Thus, implementing such models can reduce the number of road accidents to some extent and can ensure safe movement on the road. This research can be implemented on a larger scale, such as by reducing accidents between ships or boats. Though the proposed model can not stop accidents, implementation of this model surely can reduce the number of accidents taking place on roads as well as on sea-routes.

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