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Mobile Contactless Solution Using Near Field Communication (NFC)-Based Transport Payment Platform with Points Segmentation: An Improvement of Haversine Implementation

Wellanie M. Molino, Joel B. Mangaba

Abstract— The advent of global interoperability between Near Field Communication (NFC) smartphones and existing contactless technology can be a game changer for public transport infrastructure. A key application of NFC can be found in the field of contactless payment ecosystem. It can drastically change current systems of isolated technologies in public transport by providing new approaches for a national or international interoperable fare management scheme. In this study, a development of mobile contactless solution using NFC-based transport payment platform with points segmentation" was designed and developed to support public transport operators and passengers deploy NFC solutions that can enhance the efficiency of public transport system by allowing NFC-enabled mobile phone to read and write NFC card. Fares are calculated according to the distance travelled by generating consecutive pairs of distance traces called point segments where haversine algorithm was repeatedly applied for all the trace IDs. NFC enabled smartphone act as the contactless reader or a Ticket Vending Machine connected with the back end server that could provide online top-ups directly to the NFC card via payment gateway. Specifically, in this system, the Host Card Emulation (HCE) technology was used to allow tap-in and tap-out transactions to directly communicate with an NFC enabled smartphone instead of a physical sim or microchip card without collaborating with mobile network operator. The cloud-based application using Amazon web services was utilized to manage the computations of the encryption process and store sensitive data securely.

Index Terms—Near Field Communication (NFC),Card Emulation Process, Haversine Algorithm,Transport Payment System.

I. INTRODUCTION

Near Field Communication (NFC) as a promising short range wireless communication technology which finds special application in the field of mobile consumer electronics and supports smartphone usage of billions of people throughout the world that provides diverse services ranging from payment system and loyalty applications to access keys for offices and houses.

It is intended for bidirectional data transmissions over a distance of up to 10 cm and a maximum data rate of 424 kB/s and works at an operating frequency of 13.56 MHz. NFC technology is based on Radio Frequency Identification (RFID) standards according to ISO/IEC 14443 that is compatible to present contactless smartcard technologies such as Mifare or NXP's Sony's Felica. NFC is standardized in ISO/IEC 18092 [1] and ECMA-340 [2] and ECMA-352 [3] respectively. The development of the specifications is driven by the NFC Forum, a consortium of financial services, developers, manufacturers among others [4].

Transport payment system is considered as one of the most promising applications of NFC [5]. Finkenzeller [6] stated that the public transport infrastructure is of great prospective for contactless chipcards and RFID. He recommends that transport associations can be improved using contactless chipcards through the combination of cashless payment, automatic fare management [7]. Today there are already some well-established transport NFC applications, such as the Oyster Card in London, ezlink Card in Singapore and the Super Urban Intelligent Card (Suica) in Japan and Octupus Card in Hongkong [8].

At present, the Philippine government has carried on its commitment to prioritize infrastructure development. It laid down strong foundations for the Build, Build, Build (BBB) Program by compelling several key steps to implement high-impact projects to address infrastructure backlogs and support economic productivity. There are on-going major infrastructure-related masterplans and roadmaps that are being conveyed to efficiently and appropriately address the infrastructure gaps and bottlenecks in the country. One of these project is the Philippine Transport System Master Plan (PTSMP) that comprises further modernization of all transport infrastructures by developing modern technology, such as global positioning system (GPS) which will help in monitoring, tracking transport assets and lessen human error for a more seamless transportation.

Jeepneys and public utility buses in the Philippines uses two modes of payment process: the manual payment system where the conductor uses puncher to discharge tickets for the passenger, and through digital, in which the conductor uses a handheld device that print outs receipts. These prevailing methods are time-consuming, because some bus transport operators opt to calculate the amount of fare according to the distance and sometimes is the accuracy of giving change happens.

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Wellanie M. Molino, University of the East-Manila, Technological University of the Philippines.(E-Mail: wellaniemolino@yahoo.com)
Joel B. Mangaba, University of Makati (E-Mail: dr.jmangaba@gmail.com)

To lessen and somehow prevent these issues encountered, the researcher have come up with the idea of enhancing the methods of paying fares in the bus, by utilizing NFC-mobile payment system which consists of a phone to emulate the card to be used in the location detection mechanism via GPS. Based on the validations captured, the back end calculates an aggregated fare. NFC enabled smartphone act as the contactless reader that could provide online top-ups directly to the fare medium via payment gateway.

II. RELATED WORK

In today's world, technology is growing everyday and many networking communication technologies like blue tooth, Wi-Fi (wireless fidelity), infrared are existent. NFC is is a set of technologies that enable smart phones and other devices to establish radio communication with each other by bringing them all connected and provisioned with dedicated applications, which provides hundreds of millions of potential dedicated readers in contrast of the traditional dedicated payment infrastructure. All NFC peers can connect a third party NFC-enabled device with a server for any dedicated reconfiguration or action. [9] NFC device is classified into two categories:

I. Active Device: Those devices which require their own power supply. In this mode, initiator and target use self-established radio frequency to communicate.

II. Passive Device: Those devices which do not have their own power supply where target answer command are operated by initiator to call modulation scheme. Initiator do the radio frequency creation are known as Passive device[10] Different NFC tag type classifications are as follows: Tag 1 Type: The Tag 1 Type which is based on the IS0l4443A standard that are read and re-write capable which allows the users to construct the tag to become read-only. Memory availability is 96 bytes which is further sufficient to store other small amount of data or website URL with communication speed of 106 kbit/s. As a result of its simplicity this tag type is cost effective and ideal for many NFC applications Nevertheless, it is expandable up to 2k byte memory size. Tag 2 Type: The NFC Tag 2 Type is also based on IS014443A tags that are read and re-write capable and can be configured to become read-only. The basic memory size is only 48 bytes while this can be extended to 2 k byte with a communication speed of 106 kbitls. Tag 3 Type: The NFC Tag 3 Type is based on the Sony FeliCa structure and has a 2K byte memory size and has 212 kbitls data communications speed. Consequently, there is a higher cost per tag and is more suitable for multifaceted applications. Tag 4 Type: The NFC Tag 4 Type is considered to be well-matched with ISOl4443A and B standards, preconfigured at manufacture and can be either read 1 rewritable, or read-only. The memory capacity can be up to 32 kbytes and the communication speed is between 106 Kbit/s and 424 Kbitls [11].

Android is a mobile operating system (OS) based on the Linux kernel developed by Google. Based on direct manipulation user interface, Android is designed mainly for touch screen mobile devices such as computers, tablet and Smart phone with specialized user interfaces for wrist watches (Android Wear), cars (Android Auto) and televisions (Android TV). Despite being predominantly designed for touch screen input, it also has been integrated in digital cameras, game consoles and other electronic devices[14]. The proponent had gone through various existing systems and research papers that are related to this application, In this paper, transport payments are made using NFC contactless card emulated by NFC enabled smartphone via payment gateway which does not require any hardware or microcontroller device to set up the payment system which is more convenient and secure because the actual transaction between the passenger and the operator occurs in the cloud. The back end implements all the required logic for the primary fare collection processes [12]. The main drawback of this system is that it does not support offline capabilities where it should be able to use the system even when an Internet connection is not available. The main goal of another existing system is to establish payment transaction between two smartphone’s SIM Cards. This application allows mobile operator to change the normal call center calls or auto attend to a nice look mobile application. The downside of this system is that NFC is only used to send a message to the receiver to tum on the Blue-tooth.[13]

Next is the web-based bus ticket reservation System that allows the passengers to check the bus ticket availability and pay the bus ticket fare online. The advantages associated with this system are that it allows the passengers aware of the availability of the ticket and avoids to line up in a queue. But this system is a web based system and requires the user's to have a desktop system in place and user's should have a prior knowledge about the bus code (number) for their destination [14]. Another system is the BUS-TAP: A NFC based Travel Application which is consists of built in NFC service which utilizes Geo Locationing based on GPS. The current location of the bus can be monitored on its arrival at a specific stop. Also when the passenger taps on the NFC reader mounted at the bus door, the current location will be acquired and stored in the database and also while getting out off the bus the passenger taps the phone again to identify the destination location of the user. Based on the source and the destination the total travelling distance will be obtained and corresponding travel fare will be deducted from the user's account. The main difference of the existing system is that, a mobile phone is being used as a fare media which is to be tapped in the NFC reader. In this paper, NFC enabled mobile phone act as the contactless reader or a Ticket Vending Machine connected directly to the NFC card where the actual transaction occurs in the cloud. [15].

III. METHODOLOGY

A. *Research Design and Framework*

Fig. 1. Overview of the Project Methodology

Fig 1 presents the overview of the project methodology of TransFare application. This system was developed using the combined solutions of Android studio, React-native Framework, PHP, MySQL and AWS Web services. This research utilizes a hybrid System associated with Multi-Agent System, Mobile Cloud Computing and Web Service. The service-oriented architecture (SOA) and web services technologies are used in the system. SOA is a style of software design where services are distributed to the components by means of application components, using a communication protocol over a network. This architecture provides a model merging the benefits of both cloud computing and Mobile technology[17].

The above architecture describes the following process: The Admin application module writes and authenticate the NFC card with the passenger's information(initial card load balance and the card type). This NFC card is a Stored Value Ticket (SVT) and are of the credit card sized (ID-1) which conforms to the relevant ISO standards (ISO 144443). The device must be within 4cm to the NFC card before it can transmit account information. It reads the NFC card and extracts the data elements (Card's UID, Initial value, Validity Date, and Card Type. After reading the NFC card, the Admin application module sends the card's information to the server and register in the database

The Public Transport Operator's (PTO)application module validates the check-in / check-out travel information of each passenger. Entry to the bus is through the use of NFC card by holding or tapping the card to the NFC-enabled smartphone situated at the designated area inside the bus.

Upon exit, the travel price is deducted from the stored value according to the distance travelled. The entry and exit validation taps are collected and priced according to the rules of Philippine bus fare matrix imposed by the Land Transportation and Regulatory Board (LTFRB). In case the remaining stored value prior to exit is below the price of travel, the passenger can pay cash instead. The central clearing house (CCH) will validate each transaction against another set of business rules. Each transaction passing these validations will be cleared. In case the transactions represent sales or usage (implying a transfer monetary value), the cleared transactions will be settled on a regular (e.g. daily) basis.

This system can only be used by an android NFC-enabled phone and must have an internet connection and a location provider or GPS. An important part of the PTO's mobile application module is the GPS location using the Google API; this module communicates with the Google server, by sending the authentication ID to access set of traces or point segments based from the start and endpoint of the passenger's journey.The server provides the general information in the MySQL database to generate a back up with all the travel's information. It stores NFC card's information and also forward it to the CCH in order to monitor the sales and revenue reports.

Lastly, The passenger application module, allows the passenger to create an account validated by the CCH. It displays the current balance of the card including each trip history information.

B. Distance Calculation Algorithm

The distance travelled is computed from the coordinates of the origin up to the destination using the Haversine algorithm. As shown in Figure 2 is the route of the bus via Manila East Road. It has a total of 24 kilometers from the terminal. Distance and fare calculations is consist of two stages. The first stage in this method is to divide the route in small segments as the vehicle change its direction thus, each point segment is given a unique serial ID from the start of the route.

Fig. 2. Point Segmentation

The second stage is matching the received GPS traces to point segments and each trace ID is then associated with a point segment ID. To get the coordinates associated with longitudes and latitudes, the distance computation and the haversine algorithm was repeatedly applied for all consecutive pairs of traces (Ti-1, Ti) in the set T'.

The Haversine formula is an equation significant in navigation, providing great-circle distances between two points on a sphere from their latitudes and longitudes. These names follow from the fact that they are usually written in terms of the haversine function, given by haversin (θ) = sin2 (θ/2). The haversine formula is used to calculate the distance between two points on the Earth's surface specified in longitude and latitude.This is perhaps the first equation to consider when understanding how to compute distances on a sphere.

The following equation below where λ is longitude, φ is latitude, R is earth's radius (mean radius = 6,371km) is how it translate to include longitude and latitude coordinates. Note that angles need to be in radians to pass to trig functions:

$$a = \sin^2(\varphi B - \varphi A/2) + \cos \varphi A * \cos \varphi B * \sin^2(\lambda B - \lambda A/2)$$

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

$$d = R \cdot c$$

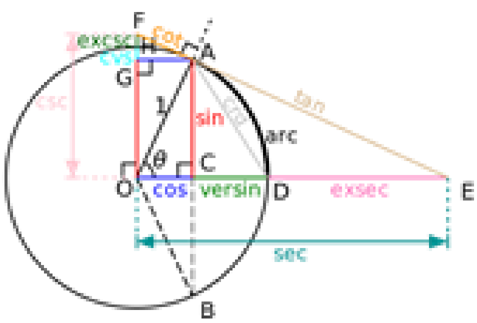

Fig. 3. Haversine Great Circle Distance

The algorithm works as follows:

1. Start
2. Tap-in to store the initial point
3. Tap –out to store the end point
4. Get displacement from polygon thru point segmentation
5. Calculate the Haversian distance between the coordinates obtained from step 2 to each of the coordinates obtained in step 3.
4. Calculate the minimum Haversian distance from the results of step 5.
5. Return the obtained distance from step 4 to the server.

IV. RESULTS AND DISCUSSIONS

Functional requirements specify specific functions or behaviors on how a system component must be able to perform. The functional requirements of the system are:

A. Registration

The system is able to provide certain concessionary recognized goups in the Philippines as mandated by the Philippine government (i.e. extra loud for people with hearing impairments). The discount products trigger an audio signal at check-in and check-out. Procedural measures must be taken to detect fraud effectively, but not each passenger has to be checked. The card registration activation process can generate NFC Tag UID by placing the NFC card against the NFC-enabled mobile. A save button will insert the newly activated card in the database.

B. Provision

The system is be able to provide the user a way to authenticate into the application, such that only the right user has access to the system and user's own private data. The Central Clearing House can create dedicated PTO accounts in the cloud, as the equivalent load retailer and bus application module owner as in Fig 4. Also, NFC contactless card allows the merchants to modify its validity period.

Fig. 4. PTO and Passenger's Module

Moreover, the system allows the commuters to use the system's services, by creating a personal, individual account from his/her NFC enabled device authenticated by the central clearing house or the merchants as in Fig 5. NFC-enabled devices provide convenience for both the transport operator and commuters. It can be used to purchase top-ups directly to the fare medium by tapping the NFC card against the mobile device.

This ensures that the user no

longer has to travel to find a ticket machine in order to top up his/her NFC card. The system provides a financial gateway platform that allows simple, private, and secure payments on a large number of websites.

C. Access Control (Validation)

The entry and exit validation taps are collected and priced according to the rules of Philippine bus fare matrix, and an over-all aggregated revenues is made to the linked bank card account of the PTO. Increasingly, this validation is being performed on the cloud. In case, a slow internet connection happens, the smartphone still performs reading of NFC cards but the private data is stored, secured, and accessed on the Cloud. The application displays audio and visual signals including the travel information of the passenger. These actions can be done after the authorization response is sent to the application for performance reasons.

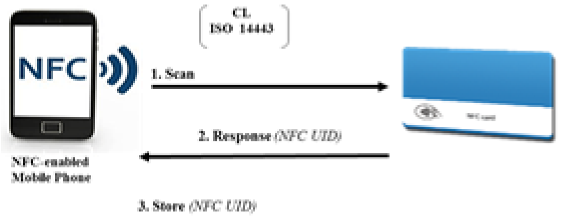

Fig. 5. NFC Read/Write

Fig 5 shows the reader/writer operating mode used in the location detection mechanism via GPS. It runs on 13.56 MHz frequency with a data transfer speed up to 242 Kbit/s. This makes it compatible to emulate the current contactless NFC cards. The key aspect of this period is to validate the proximity of the card to the NFC enabled device. Later in this process, a message was used to match it with the same message stored in the online real-time transaction monitoring module. The function of this phase is crucial to the process of preventing the relay attack.

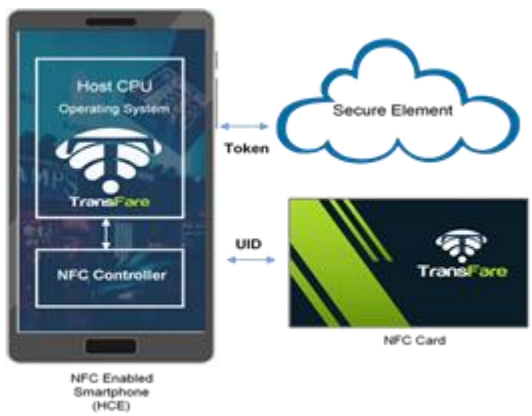

Fig. 6. Cloud-based HCE Solution of TransFare

Fig. 6 depicts the cloud based HCE system of the developed system, the data on actual usage of the public transport is real-time available for the PTO. Both during sales and during validation it is possible that sales are to be transferred from the account of the Merchants to the account of every PTO validated in the system. The PTO's TransFare mobile application in a cloud based ticketing system act as a relay between the fare medium and the back end. Transfare application communicate directly to the CCH terminal without having to go through a SE and Trusted Service Manager, and without having to conform to the many card provisioning restrictions often placed on issuers by mobile network operators when SEs are in place. HCE leverages tokenization to ensure data security and the intelligence associated with those transactions to the network and control over authentication to the issuer.This permits transport authorities the possibility to use existing NFC phones to load NFC cards securely. In all cases the passenger is enabled to do home-loading of cards by installing the TransFare application and placing the NFC card against the NFC-enabled phone for tops ups, this will automatically redirect the payment system via payment gateway.

Comparison Between Percentages of Changes:

The distance calculation were tested in two distance calculation methods namely Google Maps(on-road) and Open street map. Table 4.4 shows the comparison between the percentages and error rate of changes in distance.

Percentages of changes between On-road mobile application and TransFare

=((Point segmentation-GM)/ GM)*100%

Percentages of changes between OSM mobile application and TransFare

=((Point Segmentation-OSM)/ OSM)*100%

From the data it shows that between Point segmentation and Google Maps distance, the maximum changes in data is 1.6990291%, minimum changes in data is -7.93650793% and average Changes in data is -0.62732549%. From the analysis it can be considered that this system, it has an error of +-0.006273255% average. So the error is very much little negligible. So the acceptance of the distance data is high.

Between Point segmentation method and OSM distance, the maximum changes in data is 37.50000 %, minimum changes in data is -19.61538 % and average Changes in data is 0.63294 %. From the analysis it can be considered that this system, it has an error of +- 0.006329433 % average. So the error is very much little negligible. So the acceptance of the distance data is high.

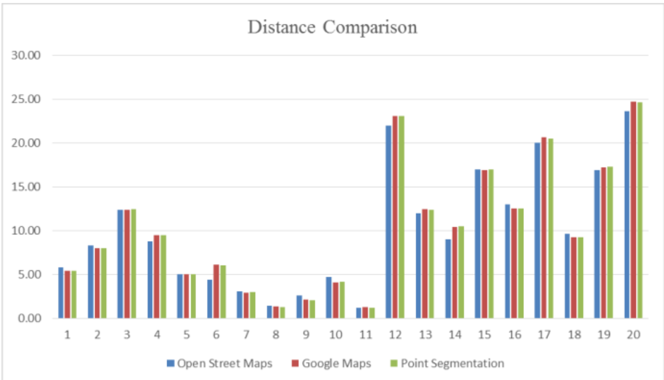

Fig 7. Distance Comparison

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Table I. Comparison Between Percentages of Changes

Distance Comparison			Error Rate	
OSM	Google Maps	Point Segmentation	Error Rate Google Maps	Error Rate Open Street Map
5.80	5.38	5.40	0.003717472	-0.068965517
8.30	7.97	7.98	0.001254705	-0.038554217
12.35	12.39	12.42	0.002421308	0.005668016
8.80	9.46	9.44	-0.002114165	0.072727273
5.01	5.06	5.03	-0.005928854	0.003992016
4.40	6.08	6.05	-0.004934211	0.375
3.09	2.95	2.98	0.010169492	-0.035598706
1.40	1.33	1.26	-0.052631579	-0.1
2.60	2.11	2.09	-0.009478673	-0.196153846
4.70	4.12	4.19	0.016990291	-0.108510638
1.21	1.26	1.16	-0.079365079	-0.041322314
22.00	23.08	23.05	-0.001299827	0.047727273
12.00	12.43	12.37	-0.004827031	0.030833333
9.01	10.43	10.49	0.005752637	0.164261931
17.00	16.89	16.95	0.003552398	-0.002941176
13.00	12.54	12.52	-0.001594896	-0.036923077
20.00	20.63	20.51	-0.005816772	0.0255
9.60	9.25	9.23	-0.002162162	-0.038541667
16.87	17.21	17.28	0.004067403	0.024303497
23.59	24.71	24.63	-0.003237556	0.044086477

Root Mean Square Error

Another verification measure is the root mean square error (RMSE). It is one of the most widely used statistics in Geographic Information System and can be used for a variety of geostatistical applications. This study measures the error between two datasets.

Table II. Root Mean Square Error Results

Distance Comparison			Error Squared	
Open Street Maps	Google Maps	Point Segmentation	OSM	GM
5.80	5.38	5.40	0.0047562	1.382E-05
8.30	7.97	7.98	0.0014864	1.574E-06
12.35	12.39	12.42	3.213E-05	5.863E-06
8.80	9.46	9.44	0.0052893	4.47E-06
5.01	5.06	5.03	1.594E-05	3.515E-05
4.40	6.08	6.05	0.140625	2.435E-05
3.09	2.95	2.98	0.0012673	0.0001034
1.40	1.33	1.26	0.01	0.0027701
2.60	2.11	2.09	0.0384763	8.985E-05
4.70	4.12	4.19	0.0117746	0.0002887
1.21	1.26	1.16	0.0017075	0.0062988
22.00	23.08	23.05	0.0022779	1.69E-06
12.00	12.43	12.37	0.0009507	2.33E-05
9.01	10.43	10.49	0.026982	3.309E-05
17.00	16.89	16.95	8.651E-06	1.262E-05
13.00	12.54	12.52	0.0013633	2.544E-06
20.00	20.63	20.51	0.0006503	3.383E-05
9.60	9.25	9.23	0.0014855	4.675E-06
16.87	17.21	17.28	0.0005907	1.654E-05
23.59	24.71	24.63	0.0019436	1.048E-05
RMSE			0.1121791	0.0221075

As shown in Table II, RMSE usually compares a predicted value and an observed value (Geography on the Rocks, 2016 January 31). To quantify the improvements over existing method of distance calculation, the proponent utilized the above formula comparing it with the Google Maps measure distance, and Open Street Map.

Performance Results

The root mean square difference value of the distances for

• point segmentation method and the method using OSM data is 112.18 m.

• point segmentation method and Google Maps distance is 22.11 m.

The results obtained showed a significant improvement over the existing haversine algorithm which are not segmented. As for accuracy, the watchPosition method applied in the point segmentation accepted three (3) parameters (error, success and options) which enabled enableHighAccuracy to true. As the vehicle continue to change its current position, this method returned the current and return to updated position. In this study, instead of actually displaying the coordinates to a precise address, the system presume of asking about applying coordinates to that specific address.

The usual way is to get the address numbers on both sides of the street at the nodes where streets change its directions like an intersection. Then, the coordinates were calculated as somewhere between the nodes. Google's cameras, Captcha and Artificial Intelligence work started filling in those gaps. The 22.11 meters root mean square difference between the point segmentation and the Google Maps measure distance maybe affected by other factors such as the location service and internet connection on the smartphone which provides access to the device's location. Though it depends on the cached (last known) positions and live data using GPS, Cell-ID, and Wi-Fi. Determining which to use and trust is a matter of trade-offs in speed, accuracy, and battery-efficiency.

V. CONCLUSIONS

A new smart phone based and promising break-through service for NFC implemented public transport payment contactless solution has been designed and developed. This provision could fuel the growth of the NFC ecosystem and be lucrative by itself. Successful NFC processes between android-based smart phones and NFC card has been done. Payment collection system has been established based on the total distance travelled and corresponding travel fare was deducted from the user's account. The haversine algorithm was repeatedly applied for all consecutive pairs of traces to calculate the distance between two points considering the latitude and longitude of those places is very accurate. On the final count, it showed the total distance between the first and the last point on the GPS. This system was checked more than 200 times to solve it. The results obtained showed a significant improvement over the manual process of issuing tickets to the passenger.

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The accuracy of the developed system relies on the GPS coordinates generated through satellites while reliability of the system depends on the GPRS facility. And lastly, HCE considerably changes card emulation execution requirements and introduces entirely new business plan considerations for service providers and PTOs.

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