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Handover Enhancement in Wireless Communication-Based Train Control Systems

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***Abstract*— The paper introduces handover system by use of two radio connections fitted in the train operating on different channels as well as use of the train's location and directional information to aid in reducing ping pong during handover. The paper formulates the Global Systems for Mobiles Railway (GSM-R) algorithm to help make decisions on when to handover with the objective of minimizing the handoff latency. These measures allow seamless connection to the network while moving along the railway boundaries which improves communication. This reduces outage duration. Simulation of the system is done using MATLAB. The algorithm used is disruption free and quite effective in high speed train travel, and the handoff decision is very efficient and more exact. This will therefore significantly improve service availability and reduce latency in data communication.**

Keywords*— *Handoff latency, ping pong, train control system, wireless communication

I. Introduction

Advanced transport network is a key pillar to the modern economies in the world. Traffic jams experienced in major cities in the world have led to time wastage and inefficiency in major economic operations. In addressing and eliminating this challenge, railway transport has been advanced and expanded to serve the masses. .

In the same spirit my country Kenya is in the move to fill this space and address the traffic jams in the capital city. In the recent past a 600km railway line was constructed connecting Nairobi and Mombasa. Passenger trains and goods wagons were then introduced. This has led to a tremendous reduction in the number of tracks and buses operating in this route and consequently reduced the number of fatal accidents earlier witnessed as a result of fatigue due to long distance driving.

In the same spirit of improving transport infrastructure within the city and the diaspora the government has embarked on the process of rehabilitating the old railway lines. Nairobi Commuter Rail Service (NCRS) was introduced to carryout passenger during the rush hours within the Nairobi metropolitan. The service has been registering a daily ridership of 13,000 passengers. Each route is designated a single commuter train which is not adequate.

In addressing the high demand during the haste time, the solution is to schedule more trains moving at a closer interval. Construction of multiple railway line requires a very big investment. The easier option is developing an elaborate railway signaling and communication system which will support the railway traffic management. Railway signaling manages the flow of traffic on railway lines to avoid collisions. Trains can move closer together without collision thereby increasing train capacity.

In this research work, the system incorporates Communication Based Train Control(CBTC) system which is used globally for Mobiles railway (GSM-R) to communicate with trains in this system. This system allows for duplex communication between the train and the control Centre. For efficient control, there needs to be constant communication to ensure consistent operation. However, due to the nature of the technology which relies on cells, where communication is handed over from one cell to another, continuous communication is not entirely possible for a short time. These periods of no communication when the train crosses from one cell to another is called handover period. The handover process is characterized by channel switching from one access point to the next while data transfer is in progress. It is during this transition period that delay occurs in decision time and ping pong effects [2]. Delay is the time taken to get the sensed data from the source to the sink [14]. The break-before-make leads to periods of unavailability and packet loss. At other times inevitable packet delay and drop by the train–wayside communications, information uncertainties in trains' states may occur leading to unplanned traction/braking [13]. This is the only way of immobilizing the train state of outage.

This research demonstrates an improved communication by use of a dual antennae, a buffer and introducing a redundancy which will reduce probability of outage. The line side signaling equipment will also be reduced leading to saving on the cost of maintenance. In addition, this will further increase railway capacity by allowing trains to run closer together.

The rest of the paper is organized as follows. Section II is the related work in CBTC, section III describes the design of the CBTC, handover techniques and the preferred algorithm. In section IV the study presents the experimental setup, simulation, results and discussion. Finally, section V presents the conclusion and suggestions for future work.

II. RELATED WORK

In this section, we briefly review related research works on CBTC system that reflects on the handover process to enable the train to travel close to one another.

At present, urban rail communication based train control system adopt the wireless communication system centered on Wireless Local Area Network (WLAN). The information transmitted and received from access points [AP] is supposed to be continuous therefore achieving seamless communication connectivity. The wireless LAN operates in the open frequency band which results to some instances where the Local Area Network (LAN) may be interfered by other nearby networks or some other foreign devices connecting into the existing networks.[5]. Also when the data transfer from one AP to another is not upheld communication interfered with leading to handover failure.

A. Handover Process

Handover is the mechanism that transfers an ongoing call from one cell to another as a user moves through the coverage area of a cellular system [. The CBTC system is divided into two parts; train installed equipment and trackside equipment [4]. The handover is transmitted by the train installed equipment. The transmission procedure is in three phases: handover preparation, handover execution and handover completion. In handover preparation phase, the available train sends a measurement report to its serving cell [3]. It then follows by measurements of radio channels. It measures the reference signal received power (RSRP) and the reference symbols received quality (RSRQ) [2]. The receipt train sends a measurement report to its serving cell which decides if the user needs to do handover and identifies the target cell then it sends a handover request message to the target cell and handover is initiated. [7].

If the target cell accepts the request, it allocates the required resources for the rrecipient train and sends a handover rrequest aacknowledge message to the source cell. Upon successful handover preparation, the handover decision is made and consequently the handover command will be sent to the recipient train. The connection between recipient train and the serving cell will be released. The recipient train releases the resources of the source cell, synchronizes with the downlink of the target cell and tries to access the target cell by using the random access procedure. In the completion phase of handover, the recipient responds with a handover confirm message. Finally, the ZC handovers the communication by giving the movement authority (MA) [9].

The soft handovers are characterized Connect-Before-Break (CBB) while the hard handovers

Break-Before-Connect (BBC) [3].[4] Figure 2 shows the three main levels in signal processing. Signal reception and measurement, signal processing and reporting. Signal reception is done at layer 1(L1). Measurement of signal takes place and the right signal is filtered and presented to the next filtering layer (L2) the signal is processed and presented to layer (L3) where it is evaluated and a trigger report forwarded for execution.[17]

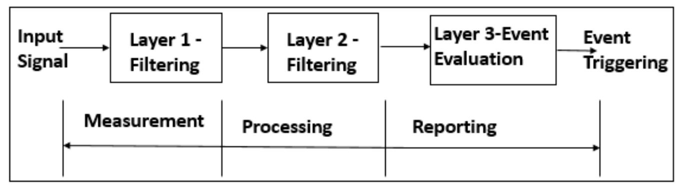

Figure 1 handover measuring filtering and reporting [10]

B. Handover Models

The handover model revolves around structural network configuration and performance metrics [6]. Besides, as one of the most important functionality of a mobile system, the handover procedure needs to be designed according to the nature of the network architecture. In the system the handover is performed with the support of antenna selection and power allocation across antennas [7].

In the Inter Base Transmitter Station BTS handover models, the mobile station (MS) scans to establish availability of other radio channels looking for BTS frequencies that may be stronger or more appropriate and reports this data to the BTS it is communicating with, the decision to execute a handover is made in the Base Station Controller (BSC).

At all times during a connection, the MS continuously sends reports for received signal strength for all the BTSs it can receive. These reports are relayed to the BSC every 480ms. Considering these measurements, the BSC will then begin the handover procedure when necessary [6].

Inter MSC handover communication is channeled from one MSC to another. Handover of calls is a complicated procedure especially when the source and next GSM cells are controlled by different MSCs. It involves all the steps in inter BTS handover procedures and additional ones at MSC level [8].

III. DESCRIPTION OF PROPOSED APPROACH

The CBTC system utilizes wireless communication to realize communication between the trains, control centre and the onboard device. The use of Redundancy, Buffer, Dual antennae and Use of 4G network facilitates continuity during handover.

TABLE I. SIMULATION PARAMETERS

No	Simulation parameters	
	Parameter	Value
1.	Cellular blocks	4 cells
2.	Cell coverage range	500 m. 1000 m.
3.	BST Power	20 w./43 dBm
4.	Antenna	14 dBi
5.	Channel model	3GPP Typical Urban
6.	Carrier frequency	2 GHz
7.	Train speed	(3 km/h, 30 km/h,120kmh)
8.	Time To Trigger	1 ms.
9.	Simulation Time	60 s.
10.	Max, Handover delay	30 ms.
11.	System bandwidth	5 Mhz. 25 RBs/TTI
12.		
13.	Time-to-Trigger	0dB/0ms, 3dB/960ms, 6dB/120ms, 9dB/0ms

The approach incorporates three stages as follows; Use of Redundancy, Buffer, Dual antennae and 4G network

- Incorporating redundancy

In order to reduce discontinued connection between a train and the control center, a redundancy is used to maintain the link and continue communication. The uploaded physical features enables the train to navigate the railway line from the start to the end [3]. The prior uploaded component eliminate the data traffic congestion during comminution. The data is available before the start of the optimization process [13]. This is important for collision avoidance.

- Train signaling using a buffer

This technique allows the train to safely navigate a terrain for a short time in the absence of control Centre signaling. The map may provide other features such as the location of other trains on the same route. This information however, being that it is time based expires after a short time only since the other trains are moving and the train cannot make informed decisions as to signaling based on past train information data. The traffic model is defined as infinite-buffer [2], an ideal acquisitive source that always has packets to send. 1 antenna is used for transmission and another for reception (One at rear while the other at the front). The initial conditions summarized in table 1 were chosen based on other related works [5, 10,9,11].

- Reducing handover interruption by using dual antennas

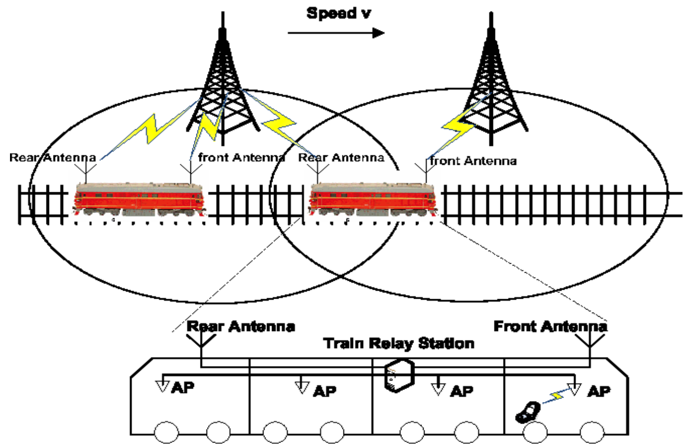

Figure 2: Dual antenna on a train during handover

As indicated in figure 2 Radio A would enter the handover zone before Radio B and consequently its connection would be handed over before that of Radio B. In this technique, one antenna is placed at the front of the train and the other is placed at the back of the train. When the train arrives at the handover zone, the radio at the front of the train will make a connection to the BTS ahead while the radio at the back will retain contact with the current BTS. This method allows the train to make constant connection to the network throughout the handover period. Incorporating a LTE radio network provides fast and seamless handover from one cell to another while simultaneously keeping network management simple. Frequent network disconnection can result due to the movement of vehicles at high speed [16]. LTE technology is designed to support mobility for various mobile speeds up to 350km/h or even up to 500km/h.

IV. EXPERIMENTS, RESULTS AND DISCUSSION

A. Simulation Experiments

In our simulation the performance of the dual antennae and the buffer is evaluated. The speed of travel that was considered by the CBTC by sampling is 360Km/h and train length 200m. 100 static features and 50 dynamic features considered to be distributed evenly along the length of the line for a travel time of 200s. MATLAB is used to simulate the CBTC system. Four conditions are considered; incorporating a buffer, the use of direct streaming of instructions, use of single antenna and dual antenna. Figure 3 and 4 shows the performances comparison of different data exchange rates with and without a buffer. The experiment will first incorporate a small buffer that stores a few bits at a time. The smaller buffer is then replaced with a larger buffer similar to a spreadsheet with a capacity of

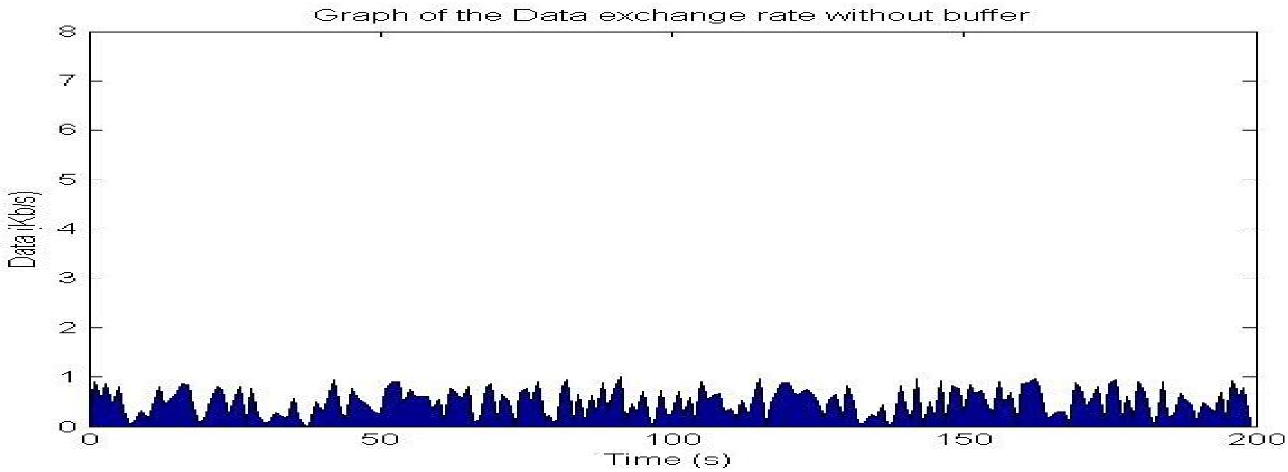

Figure 3 Data exchange without a buffer

holding more static features and the experiment run. The setup is designed to enable the handover to occurat -85 dB. Two frequencies are deployed along the length of the line. These measurements are useful to allow the BTS to determine whether to handover and to which BTS. In the single antenna,RSS measurements are sent every four cycles, the indicator used in decision making lags behind the actual.

B. Experimental Results

The experiment focuses on handover at different scenario.

- Use of a buffer

The buffers are global and are used to transport signals between the processes. Thus, each process can specify to which buffer a signal should be written or from which buffer a signal should be read [15]. In order to test the effectiveness of a buffer, 200 features are used i.e. 100 static features and 50 dynamic features. These features are distributed evenly along the length of the line for a travel time of 200s. Each feature generates data of 100Kb. Figures 3 and 4 show the results of using buffer as opposed to direct streaming of instructions.[2]

20 Mbs of data is sent to the train over the network over a period of 200s of a journey. The data is evenly spread as shown in the figure 3. The set up may have a small buffer that stores a few bits at a time.

Figure 4 shows data exchange rates when using a large buffer similar to a spreadsheet containing all static features on the route. The bulk of the data is downloaded at the start of the journey thereby reducing the burden on the network during the rest of the journey. This also allows for smooth operations even in periods of short signal outage. Before handover, the network has to store bits in anticipation for the outage to be after handover is complete. Furthermore, bits were sent during handover by either party have to be resent. Having few bits to save and resend presents the network with less burden only requiring little memory for saving bits.

- Dual Antenna

Sine waves shown in Fig.5 were used to test the effectiveness of dual antennas. The waves were modulated with random noise which would be present in the atmosphere and thereby present the problem of ping pong effect. Ping pong effect as can be seen in the figure above occurs when the signals are almost the same magnitude. Two frequencies are deployed along the length of the line. The setup is designed such that handover is supposed to occur at -85 dB.

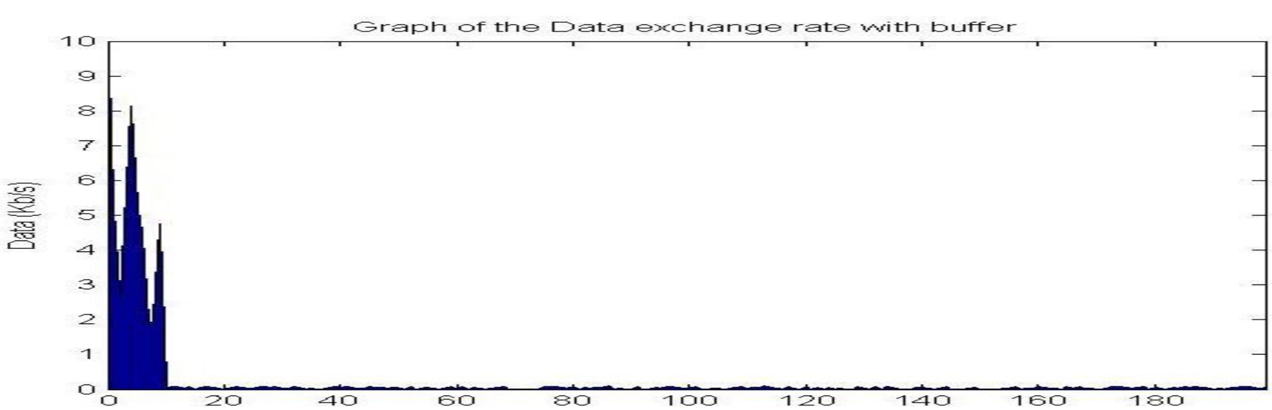

Figure 4: Data exchange with a buffer

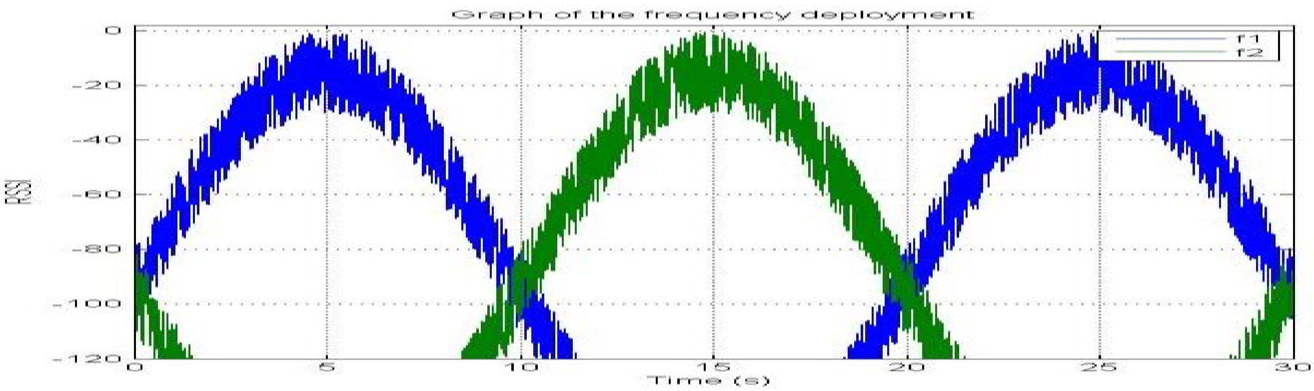

Figure: 5 Signals with random noise

- Redundancy

By use of dual antenna as frequencies coverage between two access points are acheived. The two frequencies increase redundancy and capacity. During handover, the mobile has to maintain the existing connection, make a connection with the next cell then forward the data from the existing connection to the new one, then terminate the existing connection. To this end, a redundancy is used to reduce discontinued connection between train and control center and maintains the communication link in the entire handover period.

- Handover at different speeds

Handover activation Settings for cells of radius 500m and speed value of 3, 30, 120 Km/h. then the handover is subjected to the following activation settings as shown in figure 6: (0dB/0ms), (3dB/960ms), (6dB/120ms) and (9dB/0ms).

The evaluation was based to choose a best handover initiating setting. Increasing the Hysteresis margin and decreasing values of Time to Trigger Timer (TTT)

For

UE's going at 120 Km/h (6dB/120ms) triggers more handovers followed by (3dB/960ms) because the hysteresis will be easier to be fulfilled at this speed. However, this does not mean to choose the setting which can result in least handovers because a number of necessary handovers are needed.

Since the handover is more likely to occur frequently as the speed increases, this results in an increasing system delay under all handover settings being evaluated. The (0dB/0ms) and (9dB/0ms) have a slightly higher delay due to lack of TTT mechanism at all speed scenarios as compared with the other handover settings. (3dB/960ms) has the smallest total system delay at 3, 30, 120 km/h as indicated in figure 7.

A. DISCUSSION

In evaluating the performance of the handover, the simulation results captured the following performance; Fig 6 and 7 displays the dual antenna handover performance at different speeds. It can be seen that the dual antenna scheme handover time is faster due to the short time used in decision making. No packet is lost during this handover procedure. The small delay seen is due to information exchange by user

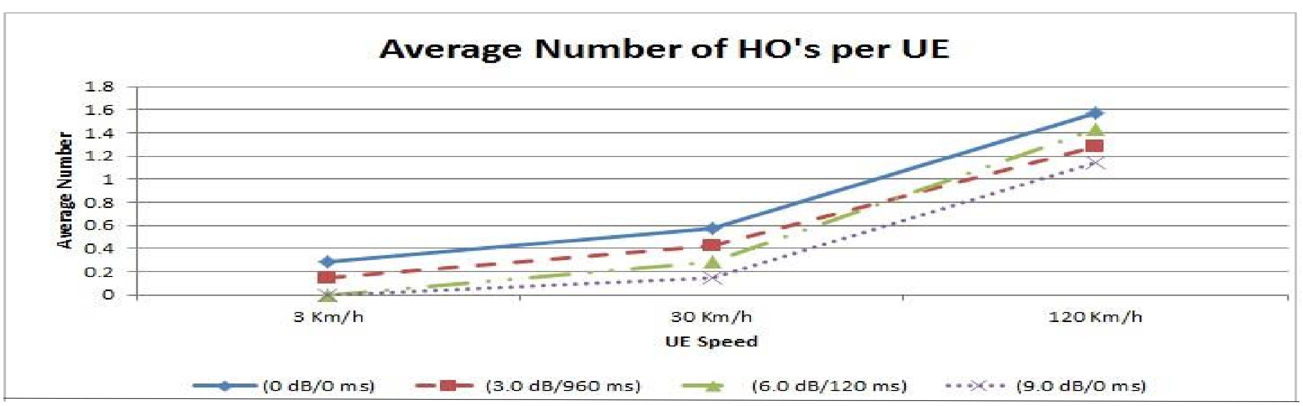

Figure 6: Effect of handover in different speeds

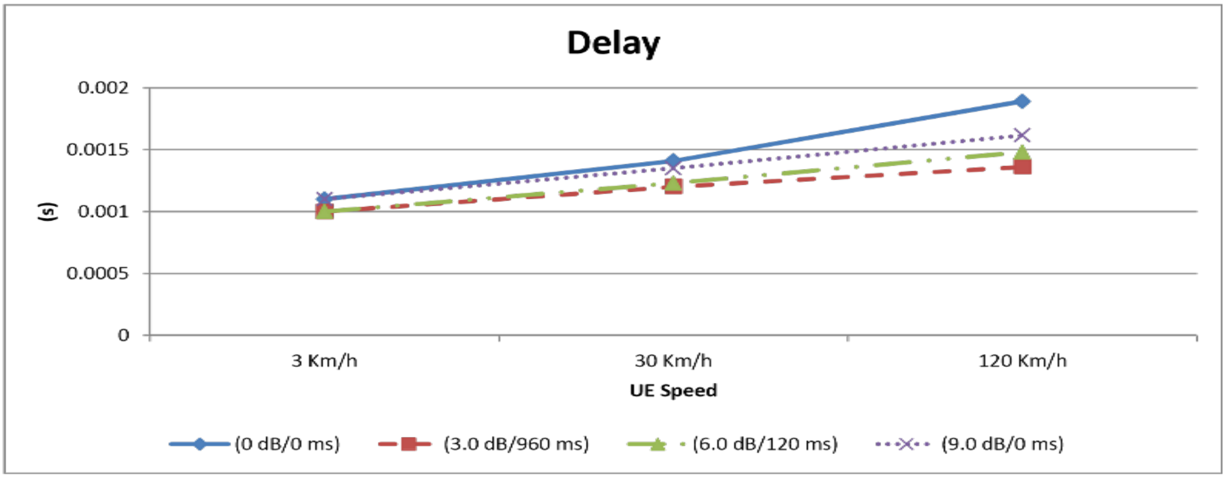

Figure 7: Handover delay

equipment (UE) before the establishment of the new path. The performance metric success rate of the handover is 99.5%.From figure 4 it can be observed that the use of a buffer reduces the burden of data exchange on the network. The large bulk is already stored. This facilitates smooth operations even in periods of short signal outage. Due to the minimum data traffic a seamless communication of up to a speed of 120Km/h. is achieved

V. CONCLUSION AND FUTURE WORK.

Train communication in high speed trains is a challenge, but with the use of LTE there is a likelihood as opposed to to earlier technologies to overcome this challenge. One of the main goals of the LTE dual radio network is to provide fast and seamless handover from one cell to another while simultaneously keeping network management simple. LTE technology is designed to support mobility for various mobile speeds up to 350km/h or even up to 500km/h. With the moving speed even higher, the handover will be more frequent and fast. A signal buffer that is incorporated ensures that the train uses a low bandwidth for signaling.

The system handover latency is reduced by dual antennas. This research work has opened up further possibilities of study. Future work should focus on hybrid algorithms with more complex scenarios, higher speeds and high loaded systems.

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