ISSN 2278-3091

Volume 7, No.3, May- June 2018

International Journal of Advanced Trends in Computer Science and Engineering

Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse03732018.pdf

https://doi.org/10.30534/ijatcse/2018/03732018

Enhancing Service Availability during Handover in Wireless Communication-Based Train Control Systems

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Abstract

The paper introduces handover system by use of two radio connections onboard 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)algorithmto 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 very efficient and more exact.Therefore, this will significantly improve service availability and reduce latency in data communication.

Keywords: Handoff latency, ping pong, train control system, wireless communication.

1.1 INTRODUCTION

In modern economies, railway transport is popular due to its lack of traffic jams, high speeds and lower traveling fares. Trains in these countries trains run at very high speeds, upwards of 200 kph traversing between different towns, allowing people to live and work in different towns. High speed railway transport comes at the cost of pricey train and railway line installations as well as elaborate communication systems. These systems facilitate railway signaling which is a key function in train operation and railway traffic management.Railway signaling manages the flow of traffic on railway lines to avoid collisions. In the past railway signaling was achieved by dividing the railway in to sections called "fixed blocks". These blocks were physical points on the railway where the trains had to get physical clearance for it to proceed to the next block if it was clear. In order to manage train operation, timetables were used to help train operators and station masters to coordinate train movement on the blocks. Blocks are supposed to increase the capacity of the railway while avoiding collisions. This presents a problem when the railway line serves trains of different speeds. Faster trains have longer breaking distances and therefore require longer blocks while shorter trains require shorter blocks. This reduces the capacity of the block as well as forcing the train operators to reduce speeds of the fastest trains.

Moving block system was adopted in order to increase line capacity as well as accomodate high speed trains. In this system, each train sends its location to the control zone's computer which calculates a 'safe zone' around each train that no other train is allowed to enter [4].Trains can move closer together without collision thereby increasing train capacity. In this system, instruction are passed directly to the train and therefore lineside signals are unnecessary, fixed zones are done away with and train can be operated with less labour.

CBTC systems use Global System for Mobiles railway (GSM-R) to communicate with trains. 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 [5]. The break-before-make leads to periods of unavailability and packet loss.

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 describesthe 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.

2.0RELATED WORK

2.1 Handover decision based on Fuzzy

Data rate received signal strength indicator (RSSI), and mobile speed are considered as inputs of the fuzzy-based system in order to decide handoff initialization process and select the best candidate access point round a smart mobile terminal. With this inputs, the algorithm then calculates the fuzzy membership based on the number of parameters as input. These functions can also calculate approximate distances between the mobile device and the BTS and use it in membership calculation [15] The drawback of this method is that lagging or varying parameters such as RSSI, ping pong can only be reduced but not eliminated. This is because membership is calculated afresh after every sampling period and therefore the varying inputs, there is bound to be varying calculated membership.

2.2 Assisted Robust Handover Scheme

Satellite communication has large coverage, and unlike the cellular network, much less ground equipment next to the track is needed. Almost no handover is needed due to the height of the satellite. However, blind spots exist in its coverage area where there is tall building, mountains and tunnels. There is a method of Appling the wireless Local Area Networks (WLAN) as complemented for loopholes of the satellite communication. Yet its continuous coverage is much smaller than we had thought. So handovers are still required. In addition, satellite signal suffers high losses in bad weather conditions. Satellite communication links with limited bandwidth (typically 4MB) and high costs(satellite renting cost and user equipment cost) cannot meet the needs of large number of passengers. What's more, satellite communication has a considerably round link delay making it not suitable for real time application. [8]

2.3 Long Term Evolutionary LTE network

In this kind of networks, data communication between the train and Zone Controller ZCis powerful for dependability analysis but does not take into consideration of the loss connection rate between handover occurrences. In the analysis study the train sends a position message to the Zone Controller ZC. If the train does not receive a valid Authority Movement MA that corresponds to its position message send, the users views it as a data communication failure.

2.4 Novel Communication-Based Train Control (NCBTC)

The cooperative relaying train communicationsenhances the performance of CBTC systems. It is a very promising technique. CBTC system with cooperative relaying act not only as end communication points but also as relays for other trains. A spatial diversity is created to increase reliability, throughput and resistance to fading in NCBTC systems [4]

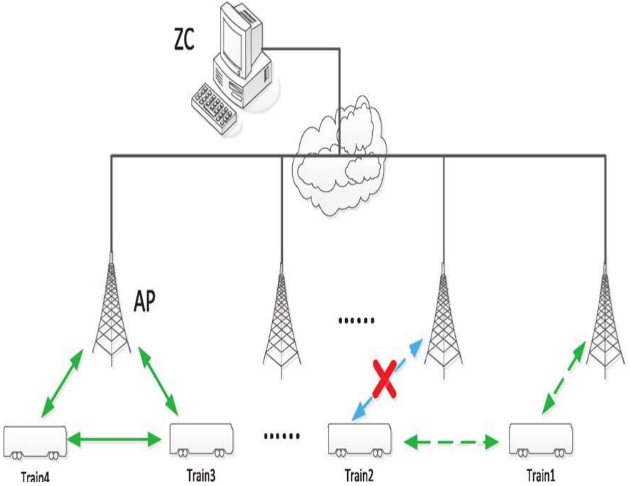

Figure 1: NCBTC system with cooperating relay[10]

However, the NCBTC cooperative relaying system can lead to a weak wireless signals in the handoff zone as the train moves from one access point to another. When all the Aps work properly co-operative relaying is used to enhance the communication between Aps and SA. When one AP fails the front train can report its position information to the behind train directly. Using train to train communication in the above system, since trains travel on the railway the signal to Noise Ratio (SNR) changes rapidly. The communication latency will be a serious problem when the SA on the train is in deep fading.

In addressing the draw back in the papers the CBTC will deliver a seamless handover by dealing with the delays in decision time during the change of frequency from one access point to the next. This will enhance service availability until the whole procedure is concluded.

3.0 COMMUNICATION – BASE TRAIN CONTROL SYSTEM

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. Handover model involves in structural network configuration and performance metrics. 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 [14]

In the Inter BTS handover the mobile station (MS) scans 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 [20].

Inter MSC handover communication is channel from one MSC to another. Handover of calls is a complicated procedure especially when the sourceand next GSM cells are controlled by different MSCs. It involves all the steps in inter BTS handover procedures and additional ones at MSC level [16].

3.1 Handover architecture

The architectural structure of CBTC system is shown by a dividing the communication devices two parts; train installed equipment and trackside equipment [4]. A continuous bidirectional data and voice communication is provided using wireless transmission. This communication is achieved by GSM-R and WLAN. WLAN is a popular choice for metros mass transit systems due to its availability of its equipment. Furthermore, trains in urban areas move at comparatively low speeds. The equipment installed on the train calculates the train's speed, position and direction then sends this information to the AP. This data is relayed to the ZC through the backbone. This data is used to compute the movement authority (MA) that is then relayed to each train within the zone. The equipment installed on the train, upon receiving MA computes a dynamic braking curve which ensures safe distance between trains on the track A handover model channel state diagram in figure 4

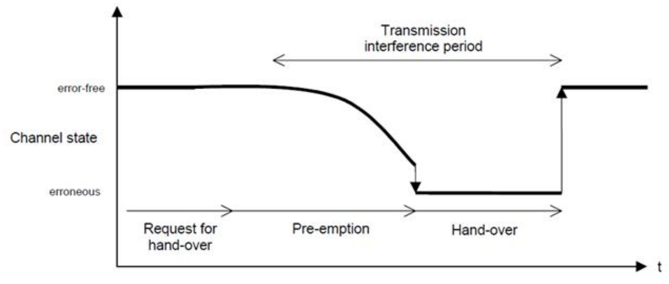

Figure 2: Error rate and radio cell handover [17]

Shows the maximum acceptable duration of transmission interference (TTI) is assumed to be 1 second as follows:

1. delay by release of the pre-empted call: around 600ms
2. delay by handover: around 300ms

Ping Pong handover (or other interferences) with a disturbance of up to 7s are not tolerated for more than 1% per hour as they could provoke MA delay > 12s (not acceptable following operational requirements [EEIG 04E117])

During handover, about 400ms, there is no data transmission between the train and the RBC. The data is queued or stored by the MSC to avoid losing it before it is transmitted through the new link. This leads to data packets being delayed for the period of the handover. During pre-emption a lower priority calls are released in the selected radio cell before handover can be completed. [17]

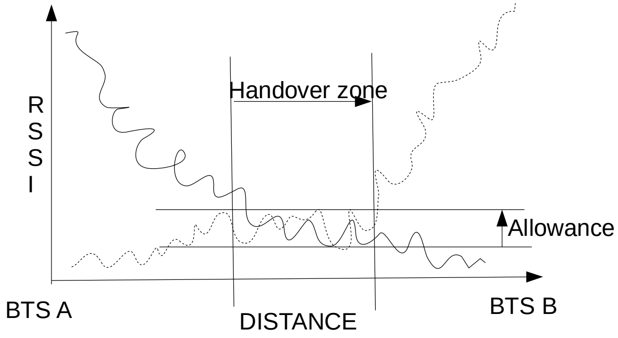

Figure 3: Handover zone and allowance.

Ping pong effect is inability of the network to decide where to handover calls which results in rapid handover from one BTS to another due to rapid fluctuation of RSSI as shown in the figure 5. Mobile Controlled Handover (MCHO)[21].

This is technique used in 3G and subsequent technologies. The MS continuously monitors signal strength from the surrounding BTS. When handover criteria are met, the MS sends a handover request to the most appropriate BTS. Network Controlled Handover (NCHO), BTSs supervise the quality of all current connections by making measurements of RSSI. The MSC will command surrounding BSs to make measurements of these links occasionally. Based on these measurements, the MSC makes decisions of when and where to effect the handover. The main failure of this method is that it demands a lot of network resources.Global System in Mobile Railway (GSM-R) is built on GSM technology, and benefits from the economies of scale of its GSM technology heritage, aiming at being a cost efficient digital replacement for existing incompatible in-track cable and analogue railway radio networks. Over 35 different such systems are reported to exist in Europe alone [20] The standard is the result of over ten years of collaboration between the various European railway companies, with the goal of achieving interoperability using a single communication platform. GSM-R is part of the European Rail Traffic Management System (ERTMS) standard and carries the signaling information directly to the train driver, enabling higher train speeds and traffic density with a high level of safety.GSM-R can support efficient communication in railway, especially in high speed trains. Its attention to the high speed subscribers is more for getting efficient communication system without any disruption.

3.2Handover process

As a Mobile Station(MS) moves toward the edge of the Base Transceiver Station(BTS) coverage area, signal strength and quality begin to deteriorate. At some point the signal from neighboring BS becomes stronger than the signal from the serving BTS. Additionally, the new BTS receives a stronger signal from the MS than that received by the old BTS. Therefore, the conversation needs to be handed over to the new BTS before the link between the old BTS and the MS becomes unusable. [13] Swapping of connectivity among different types of wires technologies is called vertical handoff. It consists of four phases: handoff initiation, network discovery, handoff decision and handoff execution. Network mobility has a very challenging issue of long handover latency and QoS as the mobile devices moves with vehicular speed. There are three methods of handover detection but this research is only interested in Mobile Assisted Handover used in GSM.(Mobile Controlled Handover (MCHO) This is technique used in 3G and subsequent technologies. The MS continuously monitors signal strength from the surrounding BTS. When handover criteria are met, the MS sends a handover request to the most appropriate BTS. In Network Controlled Handover (NCHO) the BTSs supervise the quality of all current connections by making measurements of Relative Signal Strength Indicator (RSSI). The Mobile Station Controller (MSC) will command surrounding Base Station substation (BSs) to make measurements of these links occasionally. Based on these measurements, the MSC makes decisions of when and where to effect the handover. The main failure of this method is that it demands a lot of network resources.

Relatively the Mobile Assisted Handover (MAHO) Mobile Stations measures signals from surrounding BTSs and reports the measurements back to the old BTS, so that the network can decide whether a handover is required and to which BTS. This handover strategy is employed by the high tier GSM, IS-95 CDMA, and IS-136 TDMA, but it is not used by any of the low tier PCS standard. Decisions concerning when and where to execute the handover are still made by the network, i.e., the BSC and the MSC. Handover time is approximately 1 second.

3.3 Description of Proposed Approach

In this section, we describe the approach used to enhance service availability. The approach incorporates three stages as follows; Use of

1. Redundancy
2. Buffer
3. Dual antennae

3.3.1 Incorporating Redundancy

In the course of a journey, the train interacts with the control center in charge of the area it is traversing by:

1. Transmitting its speed and location to the control center
2. The control center after acknowledging the train’s state, issues relevant signaling information to that train depending on the terrain information and the state of other trains

Terrestrial information is gathered by the control room through surveys of the area by railway official. This kind of information does not expire very quickly.

Location information is gathered by the train from the balises placed on the railway track at designated distances. With improvements in GPS accuracy, in future the location of the trains can be read using GPS. Speed information is gathered from the train’s own speed-o-meter. Location and speed measurements are information that expires quickly since the train is in constant motion and therefore have to be sent often to the control room.

Signaling a train allows it to navigate the railway line from the start to the end of its route in two ways:

1. In relation to terrestrial features such as hills, bridges, crossings etc. This prevents derailments due to over speeding on curves or slowing down at crossings.
2. In relation to other traffic on the railway line. This is important for collision avoidance.

3.3.2 Train signaling using a buffer (digitized route maps)

In the use of the buffer the trains should be equipped with map navigation technologies and the same railway map used at the control Centre should be downloaded by the train periodically so that the train can be self-navigating in the short term and rather than being passive object merely receiving all navigation instruction from the control center.

When a train leaves a station for certain routes, the train should first download a digitized map of that route. The map allows the train to know all relevant terrain features and its position in relation to the route it is traversing. The map should contain all relevant features for safe train navigation as well as all signaling information relevant to that particular terrain. The map can be refreshed as often as necessary by the control Centre.

This is a method of buffering terrestrial signaling instructions for future routes. The advantages of this method is that repetitious signaling instructions such as mandatory slow down or stops at certain junctions, curves, passing loops – for trains travelling in specified directions etc can be issued via the maps at the start of the journey for all trains travelling that route at once. This reduces the load on the communication network once the train is in motion.

This technique will allow 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. This data however may be important in the event that the trains are not moving fast such as a train which is waiting in a passing loop for a faster train to pass maybe able to know when the train on the single line section has passed. Furthermore, such information may allow the train to avoid head on collisions by estimating the entry of another train into a junction and thereby slow down accordingly.

Using such a map for decision making based on traffic has limited potential since it is highly reliant on the rate at which the map is being refreshed. The map is an invaluable tool for terrestrial decision making because the terrain is static and changes to the terrain occur rarely. This can allow the train to stop or avoid situations such as missing bridges, damaged railway line sections, crossings; slow down at corners or slopes etc.

The train can be sent ahead of time before the handover period all the signaling instructions it would require before going into the handover zone. In order to reduce the bandwidth required to signal the train, only the features layer of the map without terrain details needs to be updated constantly. Terrain layers of the map should be uploaded when the train is stationary or has not begun its journey. This layer can be refreshed only when required but not often since terrain changes are not very common.Tables 1 and 2 provide examples of the terrestrial and traffic attributes and associated signals.

Table 1

Terrestrial Attribute table

Latitude	Longitude	Feature	Signal
34.2222	0.123	Bridge	speed 100
34.2321	0.213	Crossing	stop 60 sec
34.102	0.321	Curve	speed 40
33.8524	0.222	sharp curve	speed 20
33.9452	0.132	Tunnel	speed 60

Table 2

Table 2: Traffic Attribute table

Latitude	Longitude	Feature	signal
34.1001	0.123	train 123	
33.8692	0.1122	train 231	
34.254	0.132	train 100	

3.3.3 Reducing handover interruption by using dual antennas

Hand over in GSM systems lasts for about 1 second. This means that trains that traverse urban areas at low speeds may not need any further measures taken since communication will not have been hampered much within the handover period. Secondly, urban areas tend to have more GSM BTS installations such that a mobile train could connect to several BTS at once in the event of handover failure or call dropping.

Rural areas normally receive fewer infrastructures in the way of BTS. Trains also move at maximum speed in the rural areas due to less vehicular traffic and therefore this is where the challenge of handover is most experienced. Furthermore, machines in rural areas may not receive the same amount of maintenance compared to those in the urban centers. This is why most devastating accidents occur in the rural areas.

Handover in GSM mobile units is a critical function that involves a series of complex algorithms. Simply put, during handover, the mobile unit 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, handover is a more complex procedure than call set up and therefore it has a longer delay associated with the process. Furthermore, there is probability of handover failure in which case the call will terminate and be set up again.

In order to reduce discontinued connection between a train and the control center, a redundancy is used to maintain the link and continue communication.

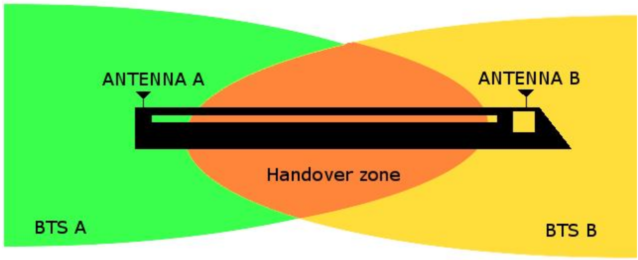

Figure 4: Dual antenna on a train during handover

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.

Radio A would enter the handover zone before Radio B and consequently its connection would be handed over before that of Radio B. In rural areas where equipment is few, it would be unexpected that the railway track will be entirely covered by four frequencies. Furthermore, size of the cell will be a macro cell with large cell area to cover as much distance as possible. GSM-R networks are dedicated networks that are meant to support only train communication. The capacity of the networks in the rural areas needs to be small since only a few trains travelling at maximum speed will be using the network. To that end, the problem of capacity of the network is secondary to handover which at high speed is more difficult to achieve due to Doppler effect. There could also be interference from public networks in the nearby towns or villages.

3.4 Algorithm

The use of this algorithm reduces bandwidth requirements during train navigation. The buffer takes into account all static features on the route and signals the train appropriately. This reduces the burden on the signaling network during high speed operation. The flow chart summarizes the execution steps.

Step 1
The static data of the navigating route is collected. All the static information is stored in the memory before navigation. The report contains information such as bridges, steep terrain, hills, corners etc.

Step 2
The dynamic data from the control Centre and track side equipment is also received, the static and dynamic information is then aggregated. The Dynamic data include; signaling information, such as the received signal strength indication, bandwidth of the head antenna for handover decisions.

Step 3
The request with the necessary information prepares for a successful train decision either for accelerating or braking. This will reduce the communication bandwidth during navigation. It also minimizes interruption between BTS during handover.

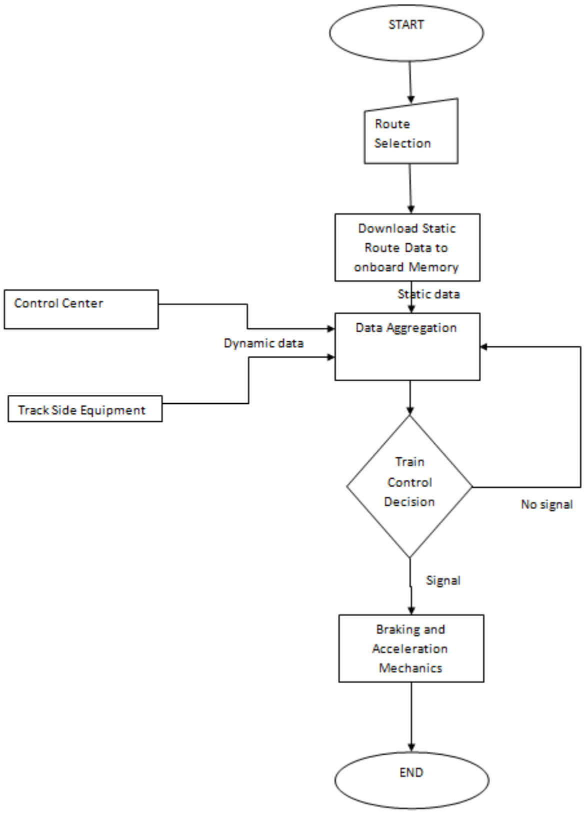

Figure 5: Flow Chart showing buffer usage

```
Start
Declare variable (route_selection, static_data,
dynamic_data)
Input route-selection data
Download static route data to onboard memory
Aggregate both dynamic and static data
If train control decision has signal, then
Apply braking and acceleration mechanism
Else
Return to data aggregation
End
```

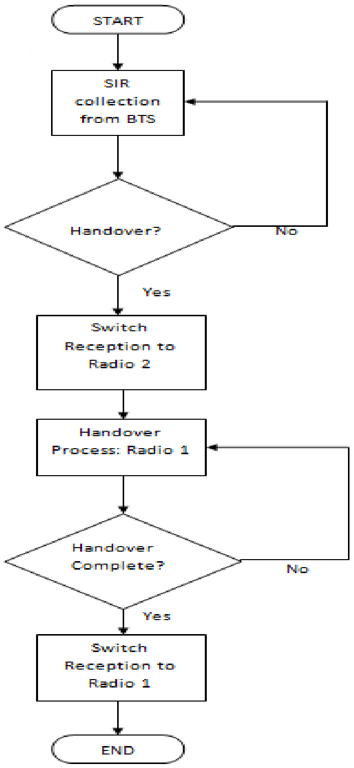

Figure 6: Flow Chart depicting procedure before and after handover

Table 4 :Algorithm listing

```
Start
Declare variables (Sir, Bts)
Collect SIR from BTS
If handover is complete then
Switch reception to radio 2
Else
Retry handover
Handover process radio 2
If handover process to radio 1 is complete then
Switch reception to radio 2
Else
Return to handover process radio 1
```

1. Communication equipment within the train consistently gathers SIR measurements from BTSs within connection range.

2. When the SIR of the current BTS drops below a certain threshold, Th_{ho}, and the SIR of the next BTS rises beyond a required threshold, Th_{ok}, then handover process is initiated.

3. First, communication between the train and the zone controller is handed over from the front radio to the rear radio. This ensures seamless communication while the front radio goes through handover. Second, the front radio hands over communication from the current BTS to the next one.

4. Third, once the front radio handover is complete, communication is handed over from the rear radio to the front radio to allow the rear radio to also handover from the current BTS to the next BTS.

Received signal strength from the current Base Station and the target Base Station $S_i(n)$ and $S_j(n)$ respectively, where n means the sampling index. The handoff decision occurs if the (RSS) S_i drops below the handover threshold Th_{HO} but is greater than the minimum RSS to allow continued communication Th_{min}. The RSSI of the next BTS must also be higher the RSSI of the current BTS by a value *H.*

$$Th_{min} < Y_i < Th_{HO} \quad (1)$$

$$Y_j(n) > Y_i(n) + H(2)$$

where both Y_i (n) and $Y_j(n)$ are the average RSS values. And, Y (n) is subject to the following equation:

$$Y(n) = \frac{1}{N\sum S(k)}(3)$$

$$k = n - N + 1(4)$$

Where *N* is the average window size and *k* is the sampling index.

The RSS is averaged to smooth it out, but that makes it a lagging indicator depending on the value of *N*. Furthermore, there is a time lag during handover decision, T_d, and handover process execution itself, T_e, as shown in fig 5. The lag during handover decision t_m is due to the time it takes to send measurements to the BTS.

$$T_t = T_d + T_e(5)$$

Four SACCH (Slow Associated Control Channel) slots are used for measurement reporting This occurs in four TCH (Traffic Channel) frames of 120*ms* each totaling delay of 0.48s. Handover execution time, T_e, is about 0.2ms between BTS, 0.532 between BSC and 1.358*s* between MSC.

$$T_d = t_m x4$$

By using two antennas the measurement frames can be sent twice as fast and therefore handover decision time is reduced by half.

In order to yield realistic path loss, the Hata Path loss model is used to estimate path loss:

From Hata model path loss equation: (Directorate-General for Communications Networks,Content and Technology, European Commission, 1999)

$$L\_P = K1 + K2Log10(f\_MHz) - 13.82Log10(h\_b) - a(h\_m) + [44.9 - 6.55Log10(h\_b)]Log(d\_km) - K \quad (6)$$

Where:

d denotes the distance between MS and the serving BTS

h_b = Base antenna height over street level in meters

h_m = Mobile station antenna height in meters

h_B = Nominal height of building roofs in meters

Averaging losses due to obstruction we can simplify the equation to:

$$L_P = K1 + K2Log10(f_{MHz}) + \varepsilon \quad (7)$$

Where:

ε denotes the Gaussian-distributed random variable ~ N (0, 8dB)

4.0 EXPERIMENTS, RESULTS AND DISCUSSION

4.1 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 10 and 11 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 holding more static features and the experiment run. The setup is designed to enable the handover occurs at -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.

4.1.1Use of a buffer

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 200 s. Each feature generates data of 100Kb. Figures 4 and 5 show the results of using buffer as oppose d to direct streaming of instructions.

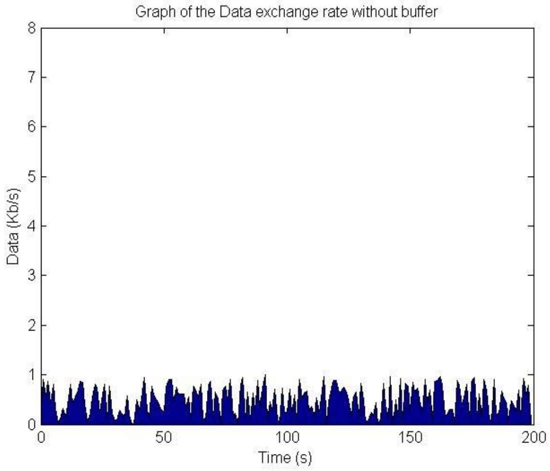

Figure 4: Data exchange without a buffer

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 4. The set up may have a small buffer that stores a few bits at a time.

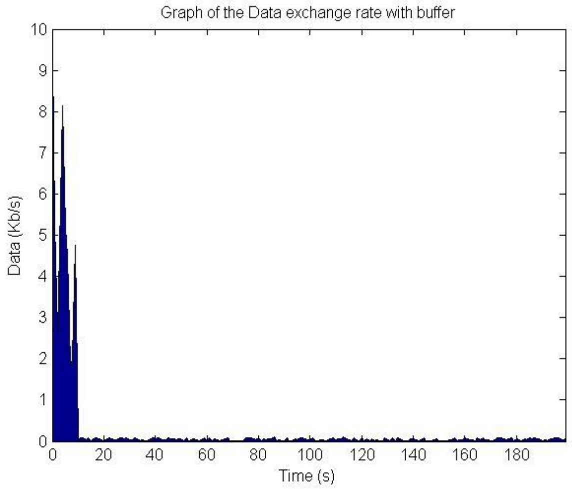

Figure 5: Data exchange with large buffer

Figure 5 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.

4.1.2 Dual Antenna

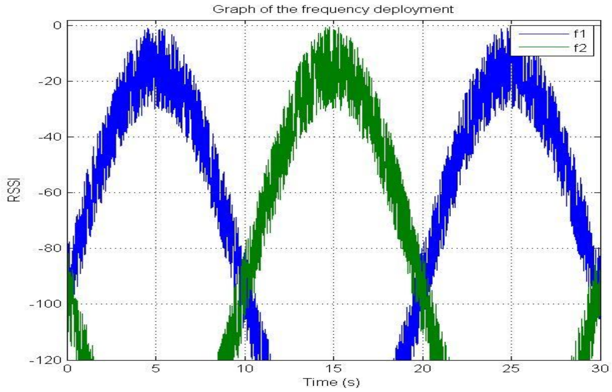

Figure 6: Signals with random noise

Sine waves as shown in Fig.6were 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. The setup is designed such that handover is supposed to occur at -85 dB. Two frequencies are deployed along the length of the line as shown in Fig.5.

Graph of delay caused by latency in sending & receiving measurements

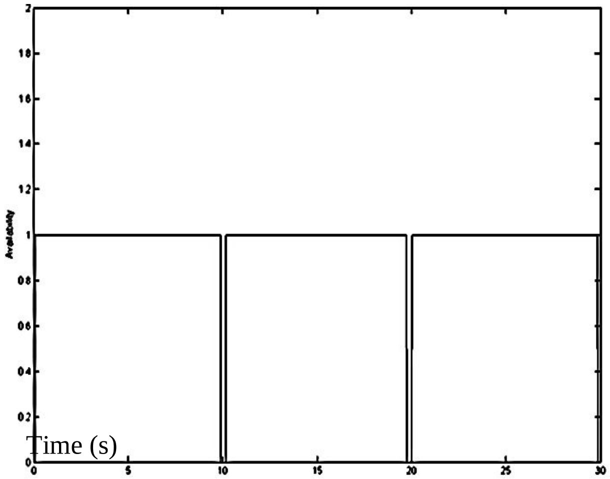

Figure 7: Delays in sending measurements

In a single antenna setup, there is only one SACCH slot and therefore it takes four TCH frames to send measurements to the BTS. These measurements are useful to allow the BTS to determine whether to handover and to which BTS. Since RSS measurements are sent every four cycles, the indicator used in decision making lags behind the actual. This creates late response in making handover decisions as shown in Fig. 6. Using dual antennas, the RSS measurements are reported twice as fast and therefore the decision time will be twice faster regardless of the speed. Even though the sending of measurements still lags behind the current RSS readings, they are twice faster than in single antenna arrangement. There is a faster response as shown in Fig. 6.

Shorter decision making time during handover eventually reduces the handover period by a similar margin. Fig. 7 shows the total handover time experienced using the single antenna setup. The total handover time is larger because a lot of time spent in decision making as well as executing the handover procedure.

Graph showing latency for single antennae

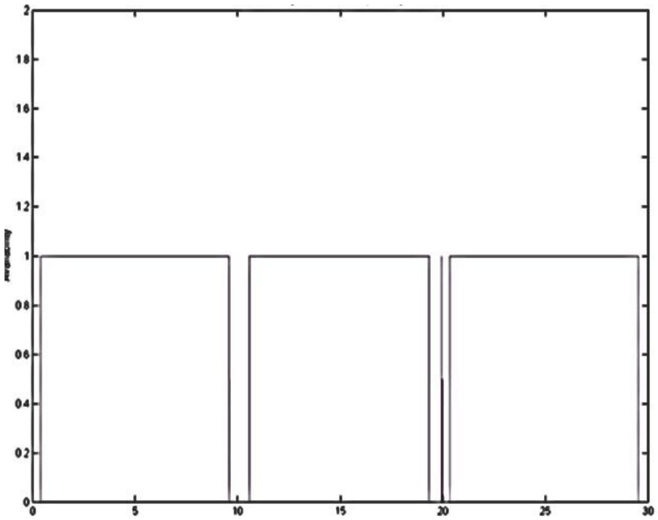

Figure 8: Total Handover time using single antenna

Figure 8shows the total handover time using dual antennas. This time is much shorter than that of the single antenna because of a shorter decision time as well as the antennas entering the handover zone at different times.

Redundancy

By use of dual antenna as seen in figure 10leads to adequate frequencies coverage between two access points. 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.

Graph showing handover latency for dual antenna

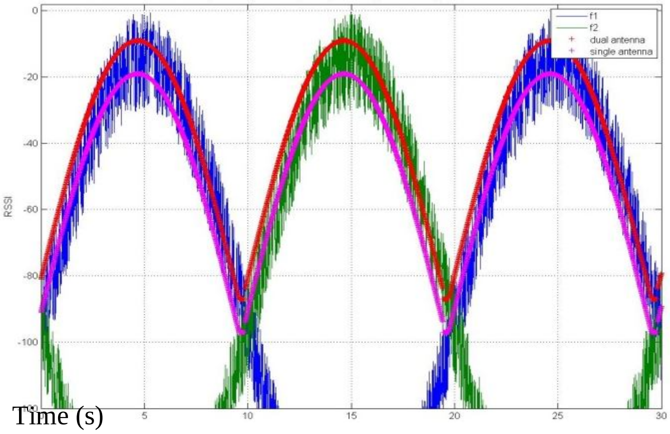

Figure 9: Total Handover time using dual antennas

4.2 Performance Discussion

In evaluating the performance of the handover, the simulation results captured the following performance. Fig 7 and 8 displays the two handover performance by using a single antenna anddual antenna respectively. From the figures 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 before the establishment of the new path. The performance metric success rate of the handover is 99.5%.From figure 7 it can be observed that the use of large 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 500Km/hr. is achieved

As the speed of the train increases, handover latency increases exponentially due to increasing frequency of handovers. According to the simulation results in figure 8, handover latency is reduced by more than half by using dual antennas. The use of dual antennas also implies modifying the wireless channel and therefore increasing the cost of equipment within the trains. Sending two SACCH using the two antennas allows the decision time to be reduced by half. Adding more SACCH slots will reduce the latency marginally while leading to more complication in the design of the communicating equipment. Make a comment on the totality of results observed.

5.0 CONCLUSION AND FUTURE WORK.

The objective of the research was to design a CBTC to enhanceservice availability during handover in vehicular networks. With this information, CBTC offers a number of major benefits over a conventional signaling systems, namely; shorter headways resulting in greater capacity, fewer trackside equipment, greater punctuality, improved safety and support for automated train operations. It was observed that, by use of two antennas placed strategically on the train it reduces the amount of time it takes to send measurements by half. The redundancy also guaranteesseamless connection between BTS until handover is complete. A signal buffer that is incorporated ensures that the train uses a low bandwidth for signaling during the journey by only receiving traffic related signaling data with an objective of reducing handover time. The application of both strategies has increased availability during handover. This paper presents the advantage of using dual antennas to reduce handover latency as well as maintain a continuous network connection during handover. This research work has opened up further possibilities of study. Future work should consider the following: Use of other technologies such as LTE which can deliver higher bandwidth in high speed communication to increase the value of train travel. Future work should also consider the proposed algorithms to other kinds of hybrid algorithms to increase quality in high speed train communication.

REFERENCES

1. L.Yi-Bing, C. Imrich, &F. Xuming, (2014). **Digital Mobile Communications Systems.** Southwest Jiaotong University.
2. Y. He, C. Liang, F. R. Yu, N. Zhao, and H. Yin, "**Optimization of cache-enabled opportunistic interference alignment wireless networks: A big data deep reinforcement learning approach**," in Proc. IEEE ICC'17, (Paris, France), June 2017. https://doi.org/10.1109/ICC.2017.7996332
3. Y. He, R. Yu, N. Zhao, H. Yin, H. Yao, and C. Qiu, **"Big data analytics in mobile cellular networks,"** IEEE Access, vol. 4, pp. 1985– 1996, Mar. 2016. https://doi.org/10.1109/ACCESS.2016.2540520
4. A. Ferrari, Itria, M. L., Chiaradonna, S., &&Spagnolo, G. O. (2011). **Model-based Evaluation of the Availability ofa CBTC System**.
5. S. Pawar, &S. Ladhe, (2013). Improving handover Latency Performance.
6. Z. Yuzhe and A. Bo, "**Quality of service improvement for high-speed railway communications," China Communications**, vol. 11, pp. 156–167, Nov 2014. https://doi.org/10.1109/CC.2014.7004533
7. H. Wang,F. Yu,L. Zhu,T.Tang,B.Ning**,Acognitive control approach to communication-based train control (CBTC) systems.** IEEE Trans. Intell. Transp.Sys.16,1676–1689(2015) https://doi.org/10.1109/TITS.2014.2377115
8. **Assisted Robust scheme for high speed Railway**(2013)
9. H. Wang, F. Yu, L. Zhu, T. Tang, and B. Ning**, "A cognitive control approach to communication-based train control systems**," IEEE Transactions on Intelligent Transportation Systems, vol. 16, no. 4, pp. 1676–1689, 2015. https://doi.org/10.1109/TITS.2014.2377115
10. L. Zhu, F. Yu, T. Tang, and B. Ning, "**Handoff performance improvements in an integrated train-ground communication system based on wireless network virtualization,**" IEEE Transactions on Intelligent Transportation Systems, vol. 18, no. 5, pp. 1165–1178, **2017.** https://doi.org/10.1109/TITS.2016.2620171
11. **L. Zhu, F. R. Yu, T. Tang, and B. Ning, "An integrated train–ground communication system using wireless network virtualization: Security and quality of service provisioning**," IEEE Transactions on Vehicular Technology, vol. 65, no. 12, pp. 9607–9. https://doi.org/10.1109/TVT.2016.2597153
12. K. Nguyen, J Beugin, Ma Berbineau, M Kassab (2015) **Modelling communication based train control system for dependability analysis of the LTE communication network in train control application.** *European modelling symposium EMS2014.*

13. S.Girhepunje, & A.Bhute, (2016**) Handover scheme of High-Speed Train Environment**
14. J P Pramod & B.C Jinaga, **"Evolution of High Speed Railway Communication system towards 5G: A Unique Scalable Model using Distributed Mobile Relays**" International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 14 (2017) pp. 4141-4144