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# A SENSOR FAULTLESS HANDOVER RESOLUTION FOR EXPRESS TRAIN ACCESS NETWORKS (ETANS)

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***Abstract:*** **Express train transportation is becoming a major tool for carrying approximately one million passengers daily in China today. To provide broadband information services for train passengers, the greatest challenge is achieving a seamless handover solution to guarantee wireless service continuity. This motivates us to incorporate sensor technology into Radio over Fiber architecture to construct an Express Train Access Network (ETAN), where the deployed sensor network captures the train movement status, which can indicate the wireless signal strength. Since the train moves on a fixed rail with fixed direction, it is possible to form an intelligent handover decision system, in which a critical movement state can exactly trigger an optical switch unit in the central station to carry out the handover procedure. Theory analyses and simulation results demonstrate that the proposed architecture can perform handover within 22 ms at a train speed of 350 km/h, providing wireless services for users without disruption, even for a cell radius as small as 100 m.**

***Keywords:*** **Express Train Access Network, ISDN, PSTN, EDI, Wireless Network Technology, Train Access Devices, Access point.**

## I. INTRODUCTION

Express train transportation is becoming a major tool for carrying approximately one million passengers daily in China today. To provide broadband information services for train passengers, the greatest challenge is achieving a seamless handover solution to guarantee wireless service continuity. This motivates us to incorporate sensor technology into Radio over Fiber architecture to construct an Express Train Access Network (ETAN), where the deployed sensor network captures the train movement status, which can indicate the wireless signal strength. Since the train moves on a fixed rail with fixed direction, it is possible to form an intelligent handover decision system, in which a critical movement state can exactly trigger an optical switch unit in the central station to carry out the handover procedure. Theory analyses and simulation results demonstrate that the proposed architecture can perform handover within 22 ms at a train speed of 350 km/h, providing wireless services for users without disruption, even for a cell radius as small as.

Recently, the Chinese express train system has been undergoing deployment nationwide. According to reports, the total mileage of the Chinese high-speed railway will reach 13,073 km by the end of 2011 and 25,000 km by the end of 2015. Additionally, the Chinese express train system has transported more than 600 million passengers in the past four years. The daily number of passengers was 237,000 in 2007, 349,000 in 2008, 492,000 in 2009, and 796,000 in 2010. It is expected to reach more than one million in 2011. Benefiting from rapid socioeconomic development,

More and more Chinese express train passengers need access to broadband information services through wireless networks while on travel. To meet the service requirements of these users, the express train system should be facilitated with a dedicated wireless access network for railway environments.

### *A. Motivation and Scope*

In this dissertation, concerned with RoF (Radio over Fiber) based network architecture aimed at efficient mobility and bandwidth management using centralized control capability of the network. In particular, the focus is mainly placed on

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RoF networks operating at mm-wave bands. In indoor environments, the electro magnetically at mm-wave tends to be coned by walls due to their electromagnetic properties at these frequencies. In outdoor environments, especially at frequencies around 60 GHz, an additional attenuation is necessary as oxygen absorption limits the transmission range. Both the cases result in very small cell as compared to microwave bands such as 2.4 or 5 GHz, requiring numerous BS to be deployed to cover a broad service area. Thus, in such networks with a large number of small cells, we realize two important issues: (1) the system should be cost-effective and (2) mobility management is very significant.

One promising alternative to thirst issue is a RoF based network since in this network functionally simple and cost-effective BS are utilized in contrast to conventional wireless systems.

### *B. Background Material*

This paper deals with the handover issues in wireless mobile networks based on cellular architecture and mm-wave bands for short-range high capacity wireless communications.

### *C. Handoff Issues*

In 2003 it was observed that popular Internet applications may not be available at high speeds due to lack of bandwidth, poor quality of service, and frequent handoffs. These problems could be partially addressed by: increasing network bandwidth using smart antenna systems and MIMO technologies, as well as improved handoff protocols that prevent connection loss when moving from one base station to another. Van Leeuwen state that the technologies discussed above are not sufficient to support broadband communications at high speeds; new modulation schemes and context-aware applications are also needed to achieve high data rates in fast moving vehicles.

1) ***Train Access Terminal Handoffs:*** De Greve stated in 2005 that high link speeds for end users could only be achieved in cellular networks by reducing the cell size to efficiently reuse spectrum. However, small cells also mean more handoffs between cells. Furthermore, Mobile Ip is not a good protocol for delivering high link speeds to fast moving users since Mobile Ip does not work well with frequent handoffs due to handoff latency, handoff packet loss, and control message load.

2) ***Passenger Handoffs:*** In 2005 Jooris studied seamless handoff, roaming, Quality of Service (QoS), and connections between heterogeneous wireless networks, such as the on board network and the trackside network. On each train the Mobile Access Router (MAR)—which is analogous to the train access terminal (TAT) in Fig. 1—will have one interface for each type of technology, and it will constantly choose the best link from the train to the outside world. Aboard a train, handoffs can occur when a mobile device is either unplugged from the trains wired network or when a mobile user moves from one Wi-Fi hotspot on the train to another.

### *D. Initial Concepts*

In this section we provide an overview of some of the initial concepts that have guided deployment of broadband Internet on trains. We also examine the FAMOUS architecture, which was developed to provide Internet access to Fast Moving Users.

Due to the mobility of trains, Internet access can be provided on them only by use of wireless links. Correia and Prasad present some of the technical challenges involved in providing wireless broadband services. The reader is referred to for a more complete treatment of the important attributes of a wireless broadband system. References address how to provide broadband communications to fast moving users. In 2001 Gavrilovich argued that a large number of small cells operating at high frequencies was the most economical and practical infrastructure for providing wireless broadband access to many users. In Gavrilovich's model, these small cells were provided by moving base stations that travel along a track beside the roadway.

### *E. Types of Handover*

There are four different types of handovers in mobile networks. They are:

Intra-system HO occurs within one system. It can be further divided into Intra-frequency HO and Inter-frequency HO. Intra-frequency occurs between cells belonging to the same network carrier, while Inter-frequency occurs between cells operate on different network carriers.

Inter-system HO takes places between cells belonging to two different Radio Access Technologies (RAT) or different Radio Access Modes (RAM).

1. ***Hard Handover:*** It is a category of HO procedures in which all the old radio links of a mobile are released before the new radio links are established. For real-time bearers it means a short disconnection of the bearer; for non-real-time bearers HHO is lossless. Hard handover can take place as intra or inter-frequency handover.

2. ***Soft Handover:*** During soft handover, a mobile simultaneously communicates with two (2-way SHO) or more cells belonging to different BSs of the same RNC (intra-RNC) or different RNCs (inter-RNC). In the downlink (DL), the mobile receives both signals for maximal ratio combining: in the uplink (UL), the mobile code channel is detected by both BSs (2-way SHO), and is routed to the RNC for selection combining.

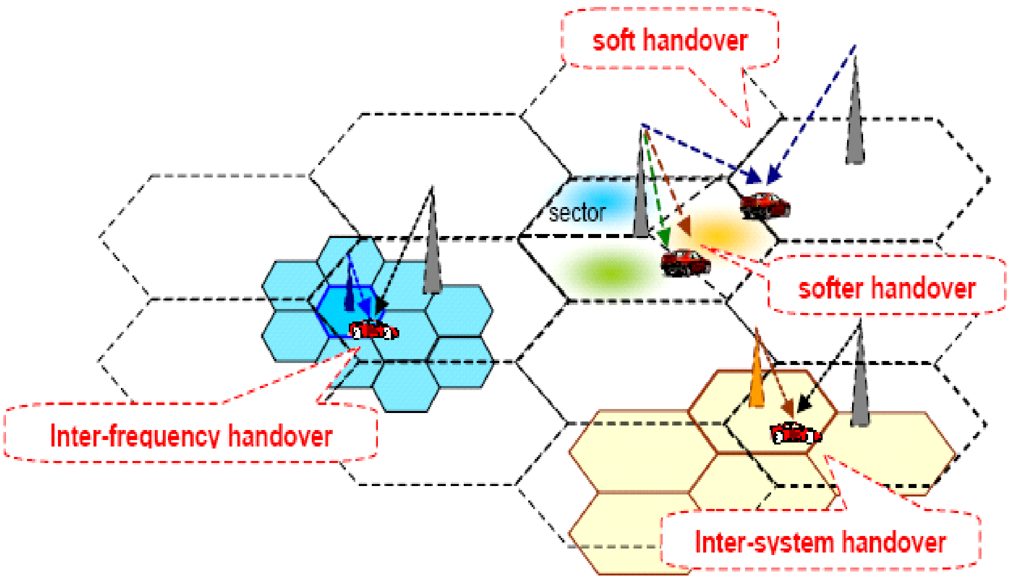


**Fig 1** Handover scenarios

| Parameters | Hard handover | Soft handover |
|---|---|---|
| Connection type | Break before Make | Make before Break |
| HO Latency | High | Less |
| Packet loss | High | Less |
| Supplementary Hardware | Not Required | Required |
| Complexity | Less | High |
| Number of BS involves | Only one | Many |

**Table 1** Hard handover and Soft handover Comparison

## II. HANDOVER DECISION SYSTEM OF ETAN

It is clear that an express train's movement has the following three characteristics: high speed, fixed direction, and a fixed path. Based on this observation, a sensor network and optical switch technologies can be combined and formed into a handover decision system dedicated for ETAN. In our theoretical model, the Standard Propagation Model (SPM) is cited for calculating path loss the channel model is slightly different from the field test results in the Beijing-Shanghai high speed railway in terms of large-scale fading effect.

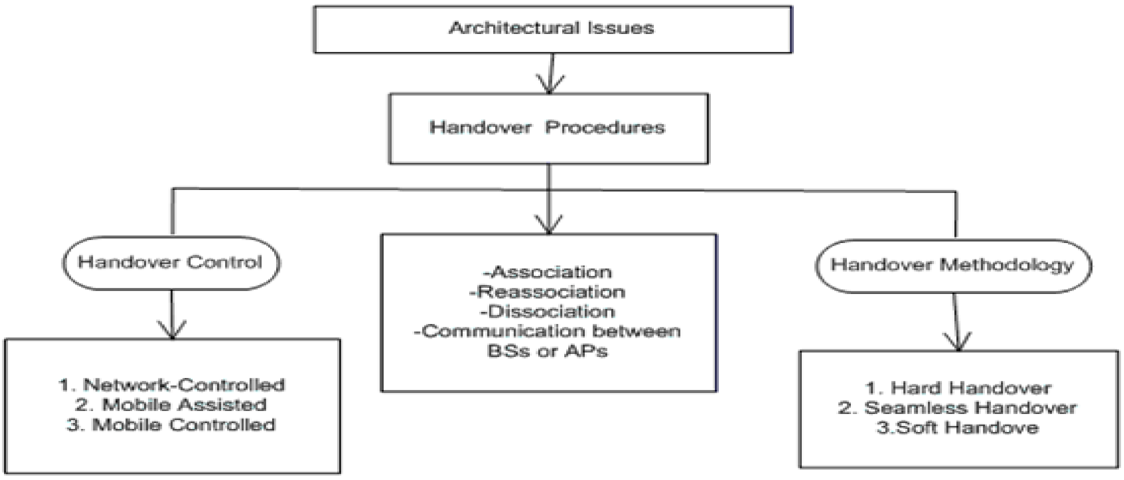


**Fig 2** Working Principal of Handover Decision System

ETAN is a high speed rail service with the speed 150 mph (240 km/h), through their average is less than half that speed. ETAN has become popular with business traveler or train traveler.

There are four possible handover scenarios in GSM

***Intra-Cell Handover:*** Within a cell, narrow-band interference could make it impossible to transmit at a certain frequency. The base station controller (BSC) could then decide to change the carrier 13 frequency.

***Inter-Cell, Intra-BSC Handover:*** This is a typical handover scenario. The MH moves from one Cell to another, but stays within the control of the same BSC that performs a handover, assigns a new radio channel in the new cell and releases the old one.

***Inter-BSC, Intra-MSC Handover:*** As a BSC only controls a limited number of cells; GSM also has to perform handovers between cells controlled by different BSCs. This handover then has to be controlled by the mobile switching center (MSC).

***Inter MSC Handover:*** Finally, a handover could be required between two cells belonging to different mobile switching center (MSC). Now both MSCs perform the handover together.

### *C. Handover Threshold Of Wireless Signal Strength And Train Movement Status*

It is necessary to build up a theoretical model to explain how our solution works by using sensor technologies. To keep the explanation easy to understand within the limited space, we set up a couple of assumptions

$$\begin{aligned} PL = K_1 + K_2 \log(d) + K_3 \log(H_{eff}) + K_4 N_{diff} \\ + K_5 \log(d) \log(H_{eff}) + K_6 \log(H_{meff}) + K_{clutter} \end{aligned} \qquad (1)$$

Where *d* is the distance from the transmitter antenna to the receiver antenna (in meters), *Heff* is the effective base station antenna height (in meters), *Ndiff* is the path loss of diffraction (in dB), *Hmeff* is the effective mobile equipment antenna height (in meters)

$$PL_B - PL_A = K_2 \log(d_B) - K_2 log(d_A) \le 3dB \qquad (2)$$

Where *dA* is the distance from location A to the BS, *dB* is the distance from Location B to the BS, and *K*2 is the correction factor for propagation distance.

$$d_{AB} = d_B - d_A \le (1 - 10^{\overline{K_2}}) d_B \qquad (3)$$

Where *dAB* is the distance from Location A to Location B. Then, the handover procedure timing requirement.

$$T_{Handover} = \frac{d_{AB}}{v} \le \frac{(1 - 10^{K_2}) d_B}{v} \qquad (4)$$

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## III. SYSTEM ARCHITECTURE

### *A. Proposed Architecture*

1. Each train is assigned a specific ID for authority to access ETAN. Light sensors are placed on the border of two neighboring cells to capture a train movement status (e.g. its location and speed). When the train passes LS-A, a handover request is triggered and sent to the Central Station (CS) to start a new link. After the train passes LS-B, another handover request will be generated to delete the old link.

2. The movement status of the train can indicate the strength of the wireless signal, because the train's movement characteristics are strongly related to the wireless signal coverage and strength information, as illustrated. It is discussed theoretically in the next subsection.

3. The CS makes a decision and switches its signal from its original BS to the next BS using an optical switch unit (which is applicable because up-to-date optical switch technology can complete switching within 10 ns).

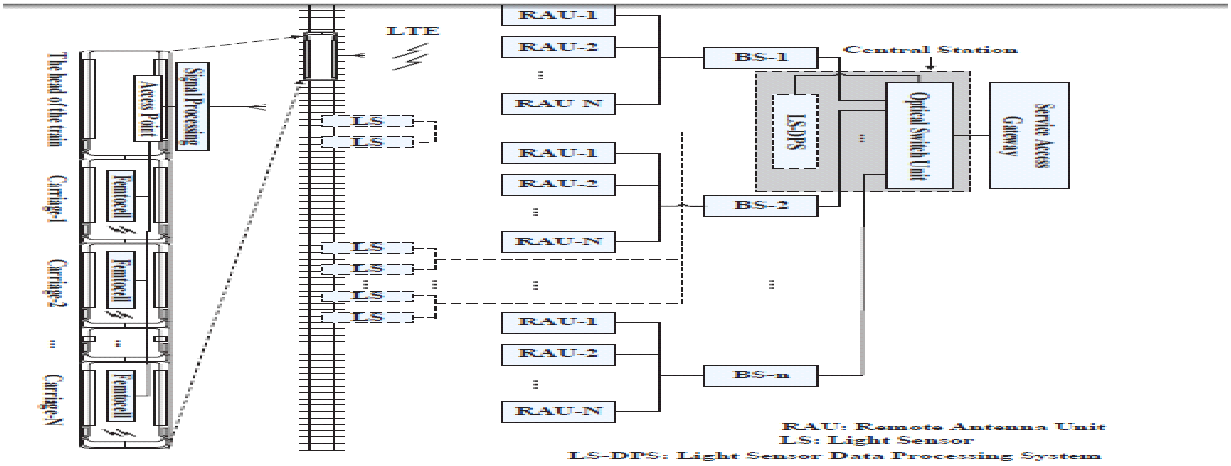


**Fig 3** Proposed Architecture For ETAN

### *B. Problem Definition*

In 2003 it was observed that popular Internet applications may not be available at high speeds due to lack of bandwidth, poor quality of service, and frequent handoffs. These problems could be partially addressed by: increasing network bandwidth using smart antenna systems and MIMO technologies, as well as improved handoff protocols that prevent connection loss when moving from one base station to another. Van Leeuwen et al. state that the technologies discussed above are not sufficient to support broadband communications at high speeds; new modulation schemes and context-aware applications are also needed to achieve high data rates in fast moving vehicles**.**

### *C. Solution Description*

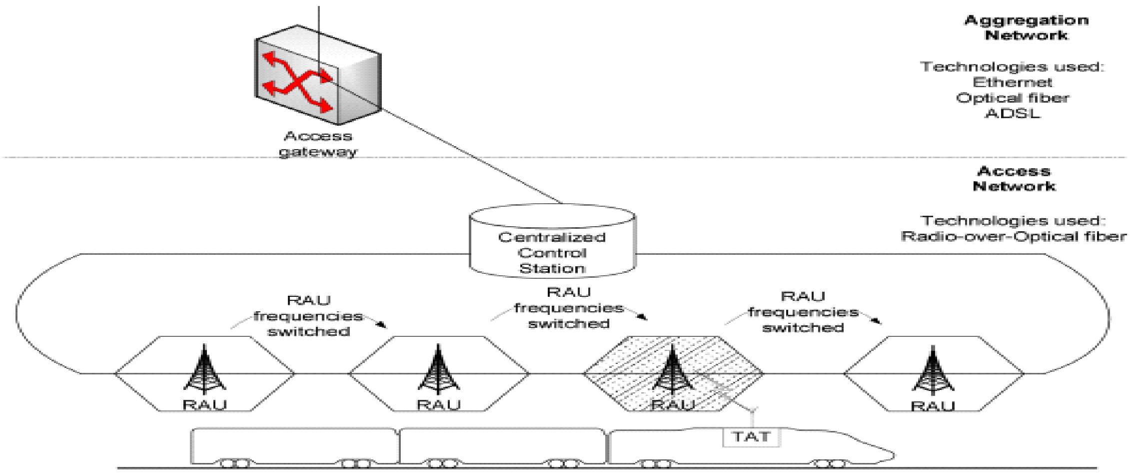


**Fig 4** Architecture for Internet Access on Trains using Radio-over-Fiber

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1) Trains may be connected to the Internet via a satellite6 link. One proposed architecture has been developed by ACCORDE, a company specializing in developing satellite RF equipment. Their architecture consists of communications, pointing, and distribution subsystems. The communications subsystem consists of an antenna, a satellite transmitter, and a modem (same as the train access terminal.

2). A pointing system performs satellite acquisition and tracking, while the distribution system uses optical fiber links to distribute the signal between the modem and each of the cars on the train. Within each car is an IEEE 802.11 or IEEE 802.16 access point. It should be noted that emerging technologies such as multi-beam lens antennas may lead to improvements in the quality of the satellite signals received on trains.

## IV. SYSTEM ANALYSIS

### *A. Description of Working Group*

Electronic Data Interchange (EDI) is a set of protocols for conducting highly structured inter-organization exchanges, such as for making purchases or initiating loan requests. The initial RFC1767 defined the method for packaging the EDI X12 and UN/EDIFACT transactions sets in a MIME envelope. However, several additional requirements for obtaining multi-vendor, inter-operable service, over and above how the EDI transactions are packaged, have come to light since the effort concluded. These currently revolve around security issues such as EDI transaction integrity, privacy and non-repudiation in various forms.

Additional requirements that mimic many of the heading fields found in X.435 EDI messages (e.g.; Interchange Sender, Interchange Recipient, interchange Control Reference, Communications Agreement ID, and Syntax Identifier) are also needed to support exchanges by point-to-point, FTP and SMTP protocols. Many believe these heading fields are best described in XML. Standards in these and other areas are necessary to ensure inter-operability between EDI packages over Internet.

| | UNGTDI | EDIFACT | ANSI X. 12 |
|---|---|---|---|
| Start of Interchange | STX | UNB | ISA |
| Start of Group | BAT | UNG | GS |
| Start of Message | MHD | UNH | ST |
| End of Message | MTR | UNT | SE |
| End of Group | EOB | UNE | GE |
| End of Interchange | END | UNZ | IEA |

**Table 2** VDA Comparison

### *B. Overview of Edi Routing*

| Code | Document Type | Document Type Protocol | Outbound as Content: Type |
|---|---|---|---|
| ISA | X12 | EDI-X12 | application/EDI-X12 |
| GS | X12 | EDI-X12 | application/EDI-X12 |
| UNB | Edifact | EDI-EDIFACT | application/EDIFACT |
| UNA | Edifact | EDI-EDIFACT | application/EDIFACT |
| ICS | ICS | EDI-X12 | application/EDI-X12 |

**Table 3** EDI routing

Fast Connect is EDI propriety Roaming feature. Extension of wireless connectivity seamlessly to locations different from home location is termed as Roaming.

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### *C. Process of Edi*

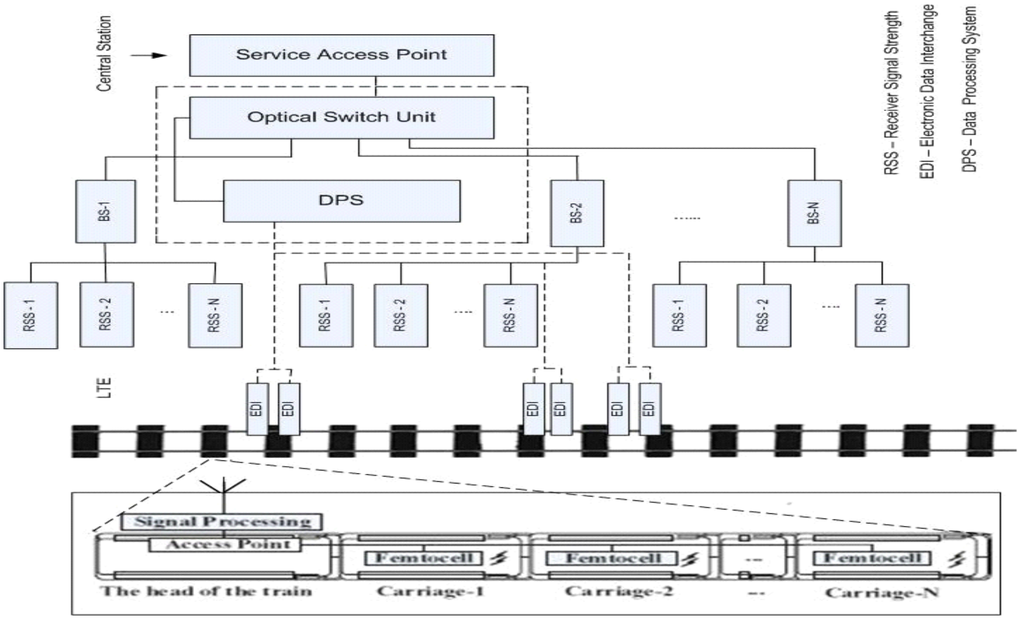


**Fig 5** Process of EDI Diagram

Mobility can be handled at different layers of the traditional TCP/IP protocol stack but in any case link layer support is necessary for providing meaningful information to initiate the handover. It can be handled at Network layer (Mobile. Etc.,), Transport layer (SCTP, variants of TCP etc.) and at session layer (SIP, SLM etc.). At each of these layers mobility management schemes have strengths and weaknesses.

### *D. Dynamic Variable Speed Compensator*

The Dynamic Variable Speed Compensator of the present invention can exist in either software and/or hardware.

In one embodiment of the present invention, the basic form of the Compensator comprises an apparatus and method configured to control a model train motor of a model train locomotive, a medium for receiving the target speed or target motor power level, an apparatus and method configured to estimate the current level of movement of the train, and an algorithm for compensating the motor movement. According to one embodiment of the present invention, the Compensator uses pulse width modulation as the method for controlling the motor. A pulse width modulator (PWM) has many different possible configurations. In one embodiment of the present invention, a method for controlling the motor involves using a random number generator (i.e., a white noise generator) to vary the frequency of the PWM. A continuous generation of random numbers will produce numbers that are evenly distributed throughout the sample pool. Thus, the average of the PWM frequency will be the value that is set for the power output. The other advantage of using the random number generator for controlling the motor is that harmonics that would normally be generated throughout the system are reduced so that their effect is effectively removed. In addition, the motor could operate in the audio spectrum without a distinct tone, or the motor could run without a human hearing the motor. In one embodiment of the present invention, in addition to PWM, a constant voltage output can also be used to enhance low speed operation where the PWM becomes inefficient.

## V. SYSTEM IMPLEMENTATION

### *A. High Speed Rail*

The international definition of high-speed rail embraces new lines with a top speed of at least 250 km/h (155 mph) and existing lines with a top speed of around 200 km/h (124 mph). As of 2011, there are four "classic" main railway lines in Britain operating at up to 125 mph (201 km/h), plus 108 km (70 mi) of purpose-built high-speed line.

The first purpose-built high-speed rail line in Britain was the Channel Tunnel Rail Link, the first section of which opened in 2003. The building of the line (re-branded "High Speed 1" in 2006) provoked discussion in the national media and specialist rail circles on the merits of constructing further high-speed lines. A second purpose-built high-speed line is now

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planned by the government — High Speed 2 — which will connect London with Birmingham, and at a later phase cities in northern England (including Manchester, Sheffield and Leeds). Alongside this scheme, are plans by the Scottish Government to build a high-speed rail line between Edinburgh and Glasgow.

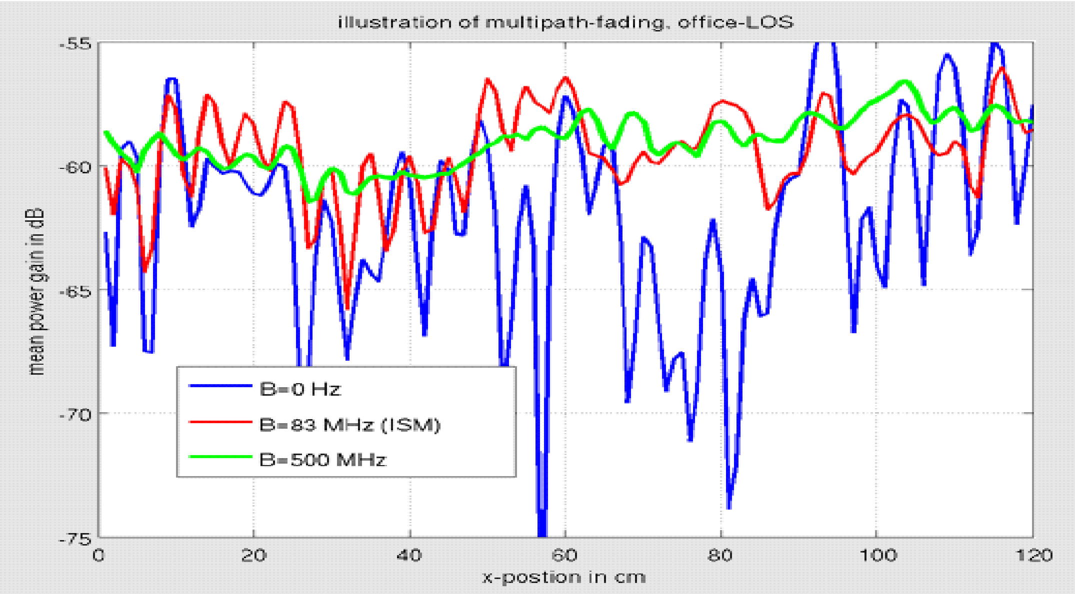


**Fig 6** Multipath Fading

***B. Mobility Management For Mobile Ip***

The mobility-enabling protocol for the Internet, mobile IP, enables terminals to move from one sub network to another as packets are being sent, without interrupting this process. An MN is a host or router that changes its attachment point from one subnet to another without changing its IP address. The MN accesses the Internet via a home agent (HA) or a foreign agent (FA). The HA is an Internet router on the MNs home network, while the FA is a router on the visited network. The node at the other end of the connection is called the correspondent node (CN).

***C. Location Registration***

When visiting any network away from home, each MN must have an HA. The MN registers with its home agent in order to track the MN's current IP address. There are two IP addresses associated with each MN, one for locating and the other one for identification. In the standard terminology, the new IP address associated with an MN while it visits a foreign link is called its care of address (CoA). The association between the current CoA and the MN's home address is maintained by a mobility binding, so that packets destined for the MN may be routed using the current CoA regardless of the MN's current point of attachment to the Internet. Each binding has an associated lifetime period, negotiated during the MN's registration, and after which time the registration is deleted. The MN must reregister within this period in order to continue service with this CoA. Depending upon its method of attachment, the MN sends location registration messages directly to it's HA, or through an FA that forwards the registration to the HA. In either case, the MN exchanges registration request and registration reply messages based on IPv4.

***D. Comparison Result***

| Parameters | 2G | 3G | 4G |
|---|---|---|---|
| Network Architecture | LAN based | Wide area cell-based | Hybrid Network |
| Driving Architecture | Only Voice | Dominantly voice ;also data | Converged data and voice over IP |
| Switching | Packed switched | Circuit and Packet | All digital with packetized voice |
| Radio Access | FDMA, CDMA, TDMA | WCDMA, CDMA 2000, ICW-136 | MC-CDMA, OFDMA |
| Database | HLR, VLR, EIR, Auk. | EHLR, VLR, EIR, Auk | EHLR, VLR, EIR, Auk |
| Data rates | 9.6 to 384 kbps | Up to 2 Mbps | 100 Mbps |

| | | | |
|---|---|---|---|
| Roaming | Restricted | Global | Global |
| Compatible | Not compatible to 3G | Compatible to 2G, 2G+ and Bluetooth | Compatible to 3G and 2G |
| Handsets | Dual mode TDMA and CDMA voice and data terminals | Multiple mode Voice, data, vidéo terminaux | Multiple mode voice, data streamed video at higher data rates. |
| Applications | SMS, Internet | Internet, SMS | Internet, MMS, Multimedia, HDTV, MTV |
| Bandwidth | 25 MHz | 5-20 MHz | 100 MHz |

***The functions are illustrated below:***

$$f_{e,i} = \frac{1}{e^{\alpha_i}} \quad f_{c,i} = \frac{e^{\beta_i}}{e^{M}} \quad f_{p,i} = \frac{1}{e^{\gamma_i}}$$

$$\text{where } \alpha_i \geq 0, M \geq \beta_i \geq 0, \text{ and } \gamma_i \geq 0$$

We used the inversed exponential equation for fe,i and fp,i to bound the result to between zero and one (i.e. these functions are normalized), and properly model users preferences. For fc,i, a new term M is introduced as the denominator to normalize the function, where M is the maximum bandwidth requirement demanded by the user. Without specified by the user, the default value of M is defined as the maximum link capacity among all available interfaces. Note that, the properties of bandwidth and usage cost/power consumption are opposite (i.e. the more bandwidth the better, whereas lower cost/power consumption is preferred).

The coefficients αi, βi, γi can be obtained using the following functions.

$$\alpha_i = x_i / 20 \qquad ; x_i : ¢ /\text{min}$$
$$\beta_i = Min(y_i, M)/M \qquad ; M = 2\text{Mbps}$$
$$\gamma_i = 2 / z_i \qquad ; z_i : \text{hours}$$

Calculation of Overall Gain function provides the best network to handoff..A candidate network is the network whose received signal strength is higher than its threshold and its position is less than the threshold. The RSS of MT can be expressed as

RSS = PL(d0) – 10nlog (d/d0 ) + Xσ

## VI. SIMULATION RESULT

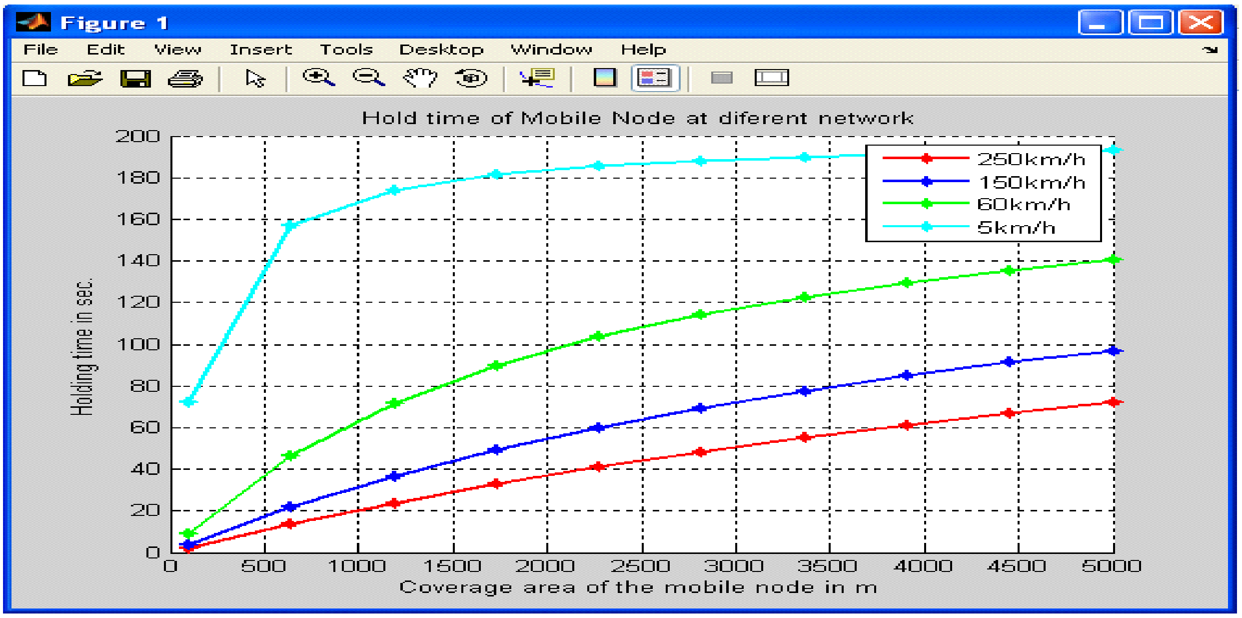


**Fig 7** Handover Probability of a Train

It shows that handover probability based on overall gain for different network has been reduced when compared with velocity based handover probability.

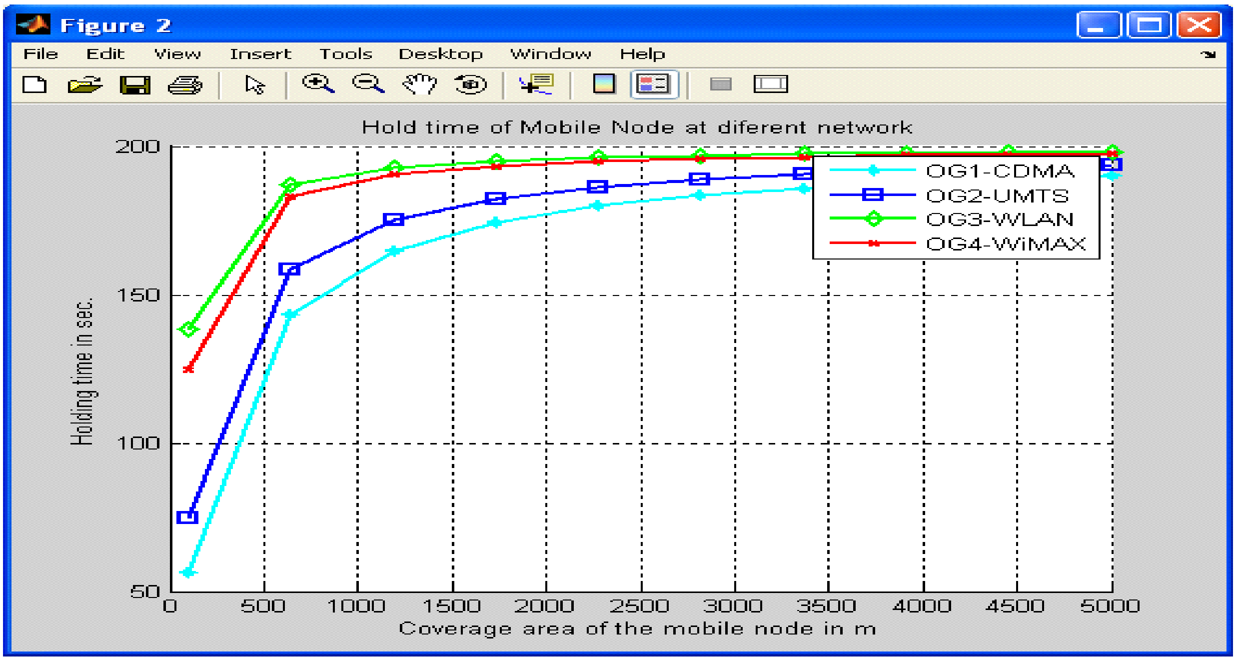


**Fig 8** Holding Time of a Train

It shows that hold time based on overall gain for different network has been increased when compared with hold time based on velocity algorithm.

The hold time of train before handoff when it travels at different velocity (250km/h, 150km/h, 60km/h, 5km/h,). It shows that the hold time increases as the speed decreases and vice versa.

## VII. EXPERIMENTAL CONTRIBUTION

we have proposed RoF based network architecture and MAC protocols that make efficient use of centralized control capability of RoF networks for fast and simple handover and effective bandwidth allocation. One should notice that the dissertation did not consider general solutions to resource management issues in RoF networks, but only proposed possible solutions for the network environments under consideration in each study. This means there is an ample scope for further study as to how to utilize centralized architecture of RoF networks for resource management issues in wireless networks.

We have developed an MAC protocol for RoF based WLAN operating in the 60 GHz band in chapter 4. This system imposes quite different requirements on system design in comparison with the conventional WLANs due to high propagation and penetration loss of the band. That is, each room in a building should be supported by at least one BS. Thus, in such network with numerous small cells, the issue of mobility management becomes very significant. The proposed MAC protocol, called Chess Board protocol, features fast and easy handover and QoS support. It is based on frequency switching (FS) codes and adjacent cells employ orthogonal FS codes to avoid possible co-channel interference as well as allow fast and easy handover. Important parameters of the protocol have been analyzed, and to investigate the properties, six variants of the protocol were considered. A simulation study has been performed to evaluate them

## VIII. CONCLUSION

The needs for info-mobility of citizen can be satisfied during their trip on trains. Such info-mobility is strongly centered on the access to internet/multimedia internet where broadband communication is a sine-qua non facility for the internet use at a decent quality of service. Nevertheless, at this stage of applications, the internet’s on trains do not have the same performance as in the case of fix hot-spots. The access of the passenger to internet inside of the train is realized in the Wi-Fi technology and is passing via the train operator portal. At the portal, the passenger can select between the services from on board (e.g. trip information, connections, other operator's legacy information) and the connection to a distant server. Different business models have been discussed and this is an open item, to be decided by the train operator.

The available technologies enable the realization of board communication with moving trains, including the HS trains running with 300Km/h. The currently reported best practice combine for the train-ground communication link the satellite telecommunication and the ground based communication, eventually completed with gap-fillers for assurance of communication continuity in tunnels.

The data and voice communications to serve the train operation performance (e.g. train monitoring, diagnosis, assistance for the crew, tele-detection, tele-medicine, electronic seat reservation … other similar utilities) have been analyzed in EC projects (such as INTEGRAIL) but have been not practically applied in the context of the broadband communication with moving trains. The train operators have opted for the commercial opportunity and priority to serve the passengers needs for info-mobility. It has been demonstrated that the offer of internet on board is increasing the attraction for the train.

## IX. FUTURE WORK

Future directions of wireless technologies can be summarized as follows:

- Achieve services making full use of wireless features such as wide-area and disaster-resistant properties
- Achieve triple-play services by next-generation FWA and support rural areas through the deployment of broadband services by WiMAX (eliminate the digital divide)
- Develop technology from 802.11abg to 802.11n/11e/11i toward the WLAN completion period
- Expand WLAN-equipped terminals (cell phones, game machines, cameras, MP3 players, 1-seg terminals, home appliances, etc.)
- A next-generation seamless network environment cannot be achieved solely by optical-access and mobile technologies. It is essential that wireless technology harmonize with and complement these technologies. We can expect the demand and significance of wireless technology to increase all the more in the years to come.

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