A Location Based Duplex Scheme for Cross Time Slot Interference Reduction in (IEEE 802.22) Cognitive Radio Based Wireless Regional Area Networks (WRAN)

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Cross time slot, IEEE 802.22, WRAN, TDD, FDD, Location based duplex, TV Band

ABSTRACT

Method of utilizing the scarce spectrum in an efficient manner is an (IEEE 802.22) is a standard for Wireless Regional Area Network (WRAN) based on cognitive radio that operates over underutilized portions of TV bands (54 to 862 MHz). Time Division Duplex (TDD) based WRAN cell has advantages such as dynamic traffic allocation, traffic asymmetry to users and ease of spectrum allocation. However, it suffers from severe cross time slot (CTS) interference when the frames of the cells are not synchronized with adjacent (WRAN) cells. In this paper, we propose a Hybrid Division Duplex (HDD) to mitigate the (CTS) interference. The proposed (HDD) system is much more flexible and efficient in providing asymmetric data service and eliminating (CTS) interference by exploiting the advantages of both (TDD) and frequency division duplex (FDD) schemes. Simulation results show that the proposed HDD scheme system can achieve 9 dB improvements in signal to interference ratio compared to conventional (TDD) based (WRAN).

نِظَام الموقع المُزدَوج للحد من التدخلات الناتجة من التبادلِ في تَخصيص الفتحة الزمنية في نِظَام شبكة المنطَقة الإقليمية اللاسلكية (WRAN) المُعتَمدة على اساس الراديوية الإدراكية (IEEE 802.22)

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المُستلخص

يعتبر محور البحث حول كيفية الاستفادة من الطيف النادرة بطريقة فعالة محوراً متميزاً للبحث في كل من الأوساط الأكاديمية والصناعية. هي معيار شبكة المنطقة الإقليمية اللاسلكية (WRAN) المُعتَمِدَة (IEEE 802.22) والمؤسسة على الراديوية الإدراكية التي تعمل على ألاجزاء غير المستغلة في نطاق التلفزيون(TV band) (54-862 ميغاهيرتز). وفي خلية المنطقة الإقليمية اللاسلكية (WRAN) يمتلك التقسيم الزماني المزدوج (TDD) مميزات متعددة مثل ديناميكية تخصيص المرور وعدم تناسق حركة المرور وسهولة تخصيص النطاق للمستخدمين. على الرغم من كل هذه المميزات إلا أن به إشكاليات مثل التداخلات الناتجة من التبادل في تخصيص الفتحة الزمنية وذلك عندما لا يوجد تزامن بين خلايا المنطقة الإقليمية اللاسلكية (WRAN) المتجاورة. وعليه تقترح هذه الدراسة تقنية للتقسيم المزدوج الهجينة (HDD) تساعد في تذليل مشكلة التداخلات الناتجة من التبادل في تخصيص الفتحة الزمنية، على أن تكون هذه التقنية أكثر مرونةً و كفاءةً في توفيرخدمة البيانات غيرالمتناظره والقضاء على التداخل، وذلك من خلال الاستفادة من ميزات كل من تقسيم ترددات الإرسال مزدوج الإتجاه وغيرالمتزامن (FDD) ومميزات التقسيم الزماني المزدوج (TDD). تظهر نتائج البحث أن تقنية التقسيم المزدوج الهجينة (HDD) المقترحة قادرة على انجاز (9dB) تحسين في الإشارة بالنسبة للتدخلات مقارنة مع طريقة التقسيم الزماني المزدوج (TDD) التقليدية المعتمدة على خلايا المنطقة الإقليمية اللاسلكية (Location Based Duplex).

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الكلمات الدالة

معيار شبكة المنطقة الإقليمية اللاسلكية، شبكة المنطقة الإقليمية اللاسلكية ، التقسيم الزمانى المزدوج، دوبلكس تقسيم التردد، الدوبلكس المعتمد على الموقع ، حزمة التلفزيون

Introduction

In developing countries, particularly India and China, more than 70% of the population lives in rural areas. Providing these people with communication services is considered as one of the key factors in order to bring them at par with the urban population in terms of economic and social development (Anh Tuan Hoang, *et, al.,*2008). The rural areas are geographically widespread, thus making it difficult to provide broadband services at a feasible cost. Installation of wired lines is not a solution for the above problem, since it is expensive to lay cables. Moreover, the demand is very low in the rural areas, thereby making it a non-viable option for the operators. The end user has to pay a huge cost in order to obtain these facilities. Hence with the advent of wireless technology, providing communication services to rural areas is likely to become viable. Today, wireless technologies such as cellular, satellite and Wi-Fi are most suited for providing internet facilities in rural areas. However there is a never ending need for low-cost services in rural areas. On the other hand, licensed spectrum below 3 GHz has significant unused capacity at any given space and time (Mark McHenry, *et, al.,* 2005). The economic potential for the TV white spaces was estimated at $ 100 billion (Thanki**,** 2009). In 2004, the FCC started investigating on underutilized TV bands for two way communication (Gerald Chouinard, 2006). Later on, November 4, 2008 FCC allowed unlicensed use of unused TV band spectrum. On February 17, 2009, the FCC released certain rules for unlicensed operation in the TV broadcast bands. IEEE 802.22 promises to be one of the major developments towards making communication services accessible in the rural areas. IEEE 802.22 operates on unused TV bands (54 to 862 MHz) and due to the favorable propagation characteristics at these frequencies, it propagates over a larger area (30-100 km) (Carlos Cordeiro, *et, al.,*2005). However when the frames of WRAN cell are not synchronized with adjacent cell, it is severely affected by CTS interference. It is the interference that occurs when two adjacent cells are in different modes during the same time slot that is when one cell is in UL whereas the adjacent cell is in DL simultaneously. This interference is present when the system operates in the TDD mode. Figure1 is a representation of CTS interference.

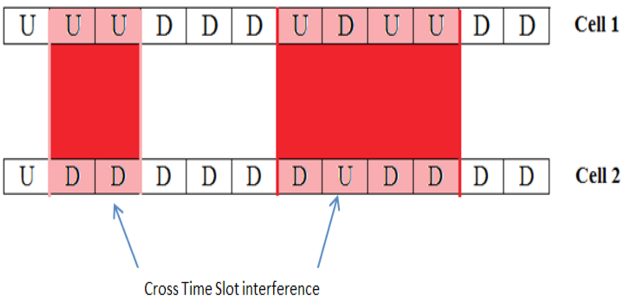

Figure 1: Illustration of Cross Time Slot Interference

The transmission time slots at the top are for cell 1 whereas those of cell 2 are at the bottom. When the time slots of both cell 1 and cell 2 are in UL or DL mode, no CTS interference is encountered. But when the slots for both cells are different (depicted by the shaded region) i.e. one cell is in UL mode and the other cell is in DL mode, the system suffers from CTS interference. Therefore, CTS interference arises when the adjacent TDD Base Stations (BSs) have different traffic symmetries or do not synchronize their frames (Ali Zamanian, *et, al.,*2001) & (Peng and Wang, 2005).

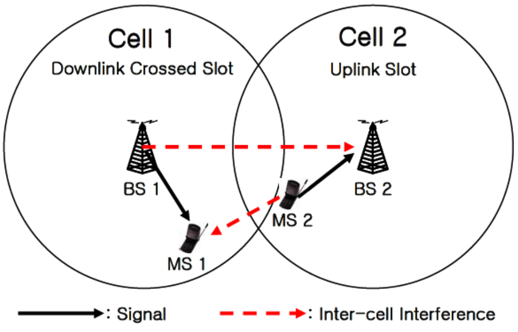

Figure 2: Cross Time Slot Interference Problem

In figure 2, the illustration of CTS using cell1-1 and cell-2 is depicted. One cell is in the UL mode whereas another cell is in the DL mode. The main interferences include BS-to-BS and MS-to-MS. BS-to-BS interference was a major challenge because it may have lower path loss exponent than BS-MS interference. This poses a serious challenge in TDD based 4G networks. To solve this issue, location based duplex system are introduced in this paper. Instead of using TDD as a duplex technique, location based approach uses TDD and FDD in the cell for duplex scheme. User location on the cell determines particular duplex scheme to user.

Material and Methods

This paper is organized as follows. Various approaches to solve cross time slot interference are discussed in the first section . In the second section, system model is discussed. Section three describes the proposed scheme. Finally, Simulation results are analyzed & discussed, followed by a paragraph gives the conclusion.

Discussions

Section One: Various Approaches to Solve Cross Time Slot Interference: Related Work

(Cha-sik Leem, *et, al.,* 2008) analyzed the performance of CR implementations in IEEE 802.22 WRAN system, in terms of the spectrum utilization rate, along with simulation results which showed that operating WRAN systems in TV bands may bring hundreds times higher spectral efficiency (Cha-sik Leem *et, al.,*2008), along with more than two times higher coverage efficiencies. In (Mainak Chatterjee *et, al.,*2008) studied the limitations of the IEEE 802.22 MAC in mesh establishment and proposed a coordinated distributed scheme for IEEE 802.22 enabled devices to establish a mesh network with reduced latency and control signaling.

Guard band aggregation scheme was proposed in (Hiroshi Harada, *et al.*, 2012), in which aggregates the multiple guard bands between digital TV signals and uses them as a control channel and/or a communication channel. They showed that the performance evaluation results of the digital TV signals were much better when the guard band is used by the proposed scheme. Furthermore, they specified the permissible transmitting power and occupied bandwidth to avoid the performance degradation of the digital TV signals. In (Cha Sik Leem, *et, al.,*2008) investigated the spectral efficiency of IEEE 802.22 WRAN spectrum overlay when it is used in TV white space. The WRAN system makes use of TV white space in the frequency ranges from 42 MHz to 862 MHz in an opportunistic way but depends on the radio regulations of the country for the WRAN service. They analyzed the spectral efficiency of WRAN spectrum overlay as a function of the power of WRAN BSs.

The effect of increasing guard distance negatively affects the spectral and coverage efficiency of WRAN system (Cha Sik Leem, *et, al.,*2008). In WRAN system transmit power of TV stations and WRAN BSs are constant, decrease in both of the spectral efficiency and the coverage efficiency were observed in counter-proportion to the increasing guard distance at the size of given area(about 400 to 800 km). This shows that there is a trade-off between the spectral efficiency and the phenomenon of interference between cells reduces as the guard distance increases.

(Ali Zamanian, *et, al.,* 2001) compared the TDD and FDD duplex method and concluded that FDD is still more advantageous as compared to TDD in wireless Internet access systems. Since, TDD adds delay to protocols that involve a response from the base station. These delays reduce protocol efficiency. In FDD systems, such delays are absent and therefore protocol efficiency is preserved. FDD access schemes, on the other hand, are not susceptible to base station to base station co-channel interference.

The features, design and implementation challenges of FDD and TDD systems for 4G wireless systems are discussed in (Peng and Wang, 2005). They have quantitatively analyzed the impact of cross-slot interference for TDD systems with respect to the co-channel and adjacent channel interfering cells. From the results, they found that the employment of sectored antennas and time slot grouping are very effective to alleviate cross-slot interference.

In (Jonathan Blogh, *et, al.,* 2003) capacity of an adaptive modulation assisted, beam-steering aided TDD/CDMA system was analyzed. Interference between TDD and FDD scheme in UMTS was characterized in (Haas, *et, al.,* 2002). They found that the interference from the TDD system to the FDD system in UMTS is decreased by increasing the BS separation distance. HDD scheme was introduced in (Daeyoung Park, *et, al.,* 2007) and it is suitable for fourth-generation mobile communication systems. The proposed mobile communication system was much more flexible and efficient in providing asymmetric data service and managing intercell interference by exploiting the advantages of both TDD and FDD schemes.

An overlaid HDD concept in cellular systems was proposed in (Jung Min Park, *et, al.,* 2011), in which divides a cell into inner and outer regions and utilizes the merits of both TDD and FDD. In (Yoon and Kim, 2004) proposed a scheduling algorithm for HDD scheme. They demonstrated that the HDD system can provide flexibility of varying uplink/ downlink transmission ratio in a multi-cell environment. In (Jens Zander, *et, al.,* 2012) proposed an analytical approach to determine the permissible transmit power for short-range secondary users under aggregate adjacent channel interference constraint in TV white space.

In (Jae Hyuck Choi and Jin Young Kim, 2010) analyzed the effect of co-existence between DTV and 802.22WRAN based systems. They set DTV as an interfering system and 802.22 WRAN as the victim system. When they shared the same spectrum, they calculated the minimum separation distance. The methods for synchronization, sectorization and time slot grouping method are discussed to eliminate BS-MS interference in (Au, *et, al.,* 2006).

An adaptive dynamic slot allocation strategy (DSA) are introduced in (Nazzarri and Ormondroyd, 2002) that resolves crossed-slot interference in multi-cell environments by dividing the coverage area of each cell into a number of distinct service zones. With the best of our knowledge, no one discuss about cross time slot interference reduction in IEEE 802.22 networks. Hence in this paper focus on methods to eliminate of cross time slot interference in future generation wireless networks.

Section Two: System Model and Assumptions

1. System Elements

The different elements of the systems are: i. (BS): The base station in our system model. We kept one BS as the desired Base Station (the center one among the three), while other two BSs as interference causing. ii. (aMS): Adjacent Mobile Station (aMS) stands for the mobile stations in the cells adjacent to the desired cell. The adjacent mobile stations are responsible for the interference to the desired mobile stations and desired base station. iii. (dMS): Desired Mobile Station (dMS) stands for the mobile stations in the desired cell. We intend to reduce the interference in the desired cell with desired base station and mobile station.

To study the interference characteristics in cellular communication, the system is considered as a cluster of cells where as in proposed system, tier by tier architecture is followed and it is shown in figure 3 a.

Consider a TV transmitter surrounded by three WRAN BS cells. The distance from the base station of TV transmitter to the boundary of that cell region (d_{DTV}) is added with the safe distance (d_{safe}) which further separates the boundary of different cell regions from the inside TV transmitter region. Now, in order to reduce the interference between the three cells outside the TV transmitter region, it is provided with a guard distance (d_{guard}) between them. Consider the middle cell of the WRAN system as the desired cell and the other two surrounding cells as the interference causing cells (figure 3 b.). Hence, only the interference caused to the WRAN BS2 cell is taken into account and the interference caused to the WRAN BS1 and WRAN BS3 can be neglected.

WRAN BSs can be employed beyond the distance $(d_{DTV} + d_{safe})$, where d_{DTV} is the DTV service range and d_{safe} is the protection range (d_{DTV} and d_{safe} are selected according to FCC rules reported in (Carlos, *et, al.,* 2005) & (Gerald Chouinard, 2006). Furthermore, d_{WRAN} denotes the WRAN BS service coverage area and d_{guard} denotes the distance between adjacent WRAN BSs. The interference caused in cell 2 (the desired cell) is due to its two adjacent cells, cell 1 and cell 3. When the TDD frames of the cells are not synchronized with each other, it causes MS-to-MS and BS-to-BS interference between the cells. Such interference is termed as cross time slot (CTS) interference. To reduce such CTS interference, each cell is divided into two regions: inner part operating by TDD in UL as well as in DL and the outer part operating by TDD in DL and FDD in UL. In a conventional FDD system, a pair of spectrum bands is used for UL and DL, but the proposed HDD scheme utilizes FDD in DL mode only. Thus, simultaneous operation of TDD and FDD is achievable in a single cell without any need of additional spectrum.

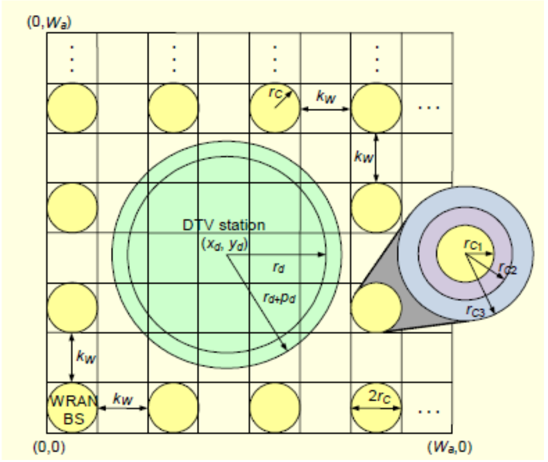

Figure 3 b: WRAN System Model

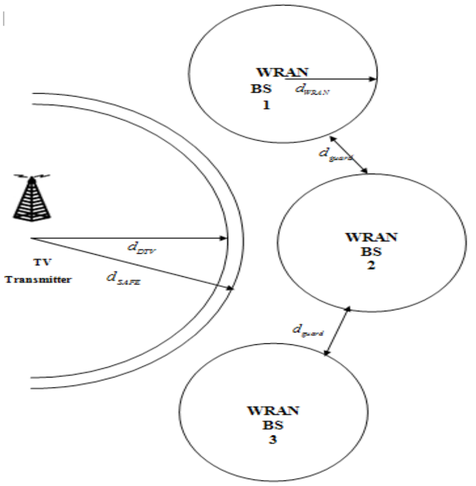

Figure 3 a: Tier by Tier Architecture

2. Interference Scenarios

It is assumed that the system utilizes a frequency currently unused by the Digital TV (DTV) in the particular area. For simplicity, here we consider only one adjacent cell. Two particular cases, i. the desired cell in *uplink* UL, and ii. the desired cell in *downlink* DL.

2.1. Desired Cell in Uplink UL,

Figure 4 shows the scenario, where the desired cell is in UL mode and the adjacent cell is in the DL mode. Therefore BS of the adjacent cell is transmitting whereas the desired cell is receiving information, resulting in BS-to-BS interference (depicted by dashed lines). Such interference usually affects the system more than the MS-to-BS interference because a line-of-sight (LOS) path may exist between the elevated BSs and the path loss exponent that exists between elevated BSs can be smaller than that between BS and MS.

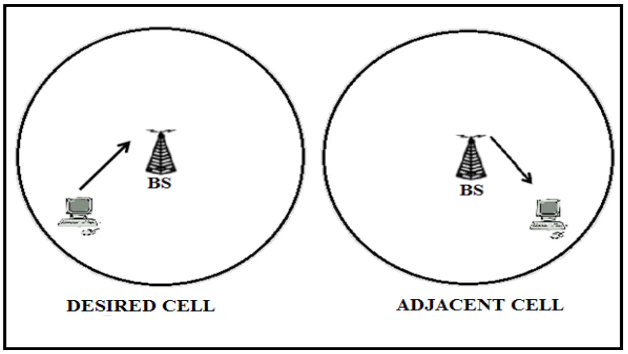

Figure 4: Interference when Desired Cell is in Uplink UL

2.2. Desired Cell in Downlink DL

Figure 5 depicts the interference scenario when the desired cell has its TDD slot in DL and the adjacent cell has is TDD slot in UL. The desired MS, receiving information from its BS, is susceptible to interference from the mobile station in the adjacent cell (depicted by dashed lines). This interference is tough to mitigate compared to the former case as the location of the MSs might keep changing.

The CTS interference poses a problem to the system that uses TDD, reducing the throughput of the system. Different approaches were considered to reduce the interference in such a systems. Frequency Division Duplex (FDD) is another alternative to TDD since FDD has the benefit of requiring no guard time between UL and DL. However, the problem with FDD is that it does not support asymmetrical data services. If the cross slot interference is so strong, then it may affect adjacent channels noticeably. Hence FDD cannot be implemented on a large scale due to the above problems.

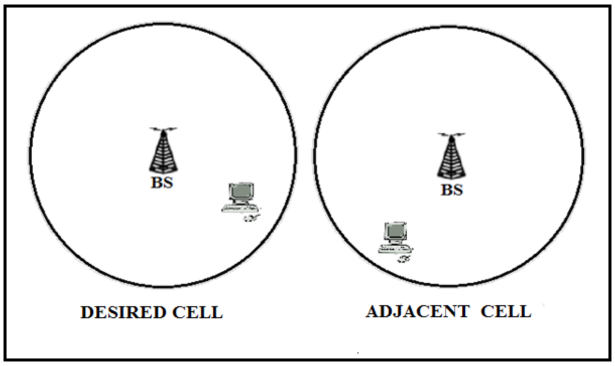

Figure 5: Interference when Desired Cell is in Downlink DL

Section Three: Proposed Technique

Figure 6 gives a description of the HDD system. The proposed HDD communication system is much more flexible and efficient in providing asymmetric data service and reduces CTS interference by exploiting the advantages of both TDD and FDD schemes.

The HDD scheme has a pair of frequency bands like in the FDD scheme, performing a TDD operation using one of the bands in such a manner that allows for simultaneous FDD and TDD operations. The important advantage of the HDD scheme is the robustness against cross time slot interference that is inherent to the TDD system, which is caused by the asynchronous downlink/uplink switching boundaries among all neighbor cells. Table 1 describes various parameters of system based on the BS EIRP (for 100[W] and 4[W] separately).

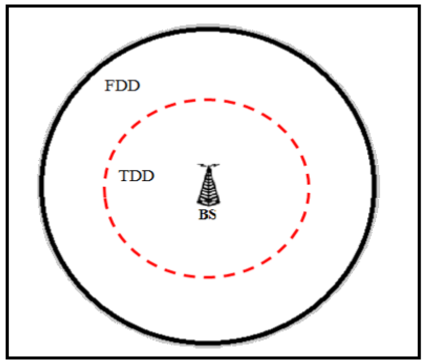

Figure 6: HDD System

Table 1: System Parameters with Respect to BS EIRP

Base Station EIRP	100[W]	4[W]
	20.0[dBW]	6.0[dBW]
Antenna height above average terrain (HAAT)	75.0[m]	75.0[m]
Required Field Strength	28.8[dB(uV/m)]	28.8[dB(uV/m)]
Path loss needed beyond 1 m	126.0[dB]	112.0[dB]
Radius of the cell	30.3[km]	16.7[km]

Mathematical Model

Case 1: Desired Cell in DL/Adjacent in UL (Worst Case Scenario)

Let us assume the MS is located at the edge of cell 2 as shown in figure 7.

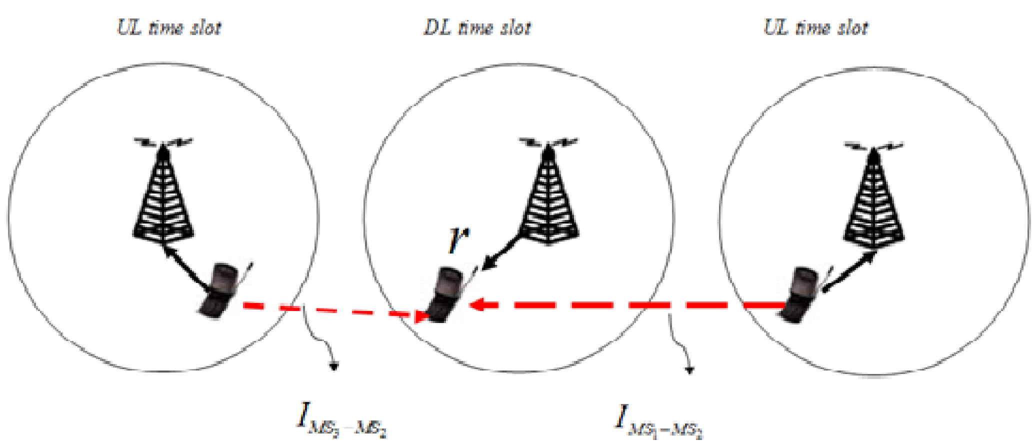

Figure 7: Worst Case Scenario in TDD Based WRAN

Cells 1 and 3 operate in the UL mode while Cell 2 operates in the DL mode. The signal power received by MSs in cell 2 from the BS in cell 2 is given by

$$S^{BS\rightarrow MS} = \alpha\mu_{BS}P_{BS}(r)^{-\gamma} \quad (1)$$

Where γ is the path loss exponent, α is a constant, P_{BS} is the power transmitted by the BS and μ_{BS} is cell loading factor of the BS, which is defined as the ratio of the number of used subcarriers to the total number of subcarriers in the OFDMA system (Daeyoung Park *et, al.*,2007).

In the traditional system, cells 1 and 3 (operating in TDD-UL) cause interference in cell 2 (operating in the TDD-DL). The interference caused to any MS in cell 2 by the MSs in the adjacent cells is given by

$$I_{DL}^{MS\rightarrow MS} = \sum_i \alpha\mu_{MS}P_{MS}(r_i)^{-\gamma} \quad (2)$$

Where 'i' is the total number of MSs in the adjacent cells and r_i is the distance between the MS in cell 2 and the i^{th} MS in the adjacent cell.

The overall signal to interference ratio (SIR) of the MS with distance from the BS is r for the conventional system is given as

$$SIR_{conv} = S_{BS\rightarrow MS} \Big/ I_{MS_1^i\rightarrow MS_2} + I_{MS_1^o\rightarrow MS_2} + I_{MS_3^i\rightarrow MS_2} + I_{MS_3^o\rightarrow MS_2} \quad (3)$$

Where $I_{MS_1^i-MS_2}$ is the interference from MS located inside the cell 1-to-cell 2 (target cell), $I_{MS_i^o-MS_2}$ is the interference from MS located outside of cell 1-to-cell 2, $I_{MS_3^i-MS_2}$ is the interference from MS located inside the cell 3-to-cell 2 and $I_{MS_3^o-MS_2}$ is the interference from MS located outside of cell 3-to-cell 2.

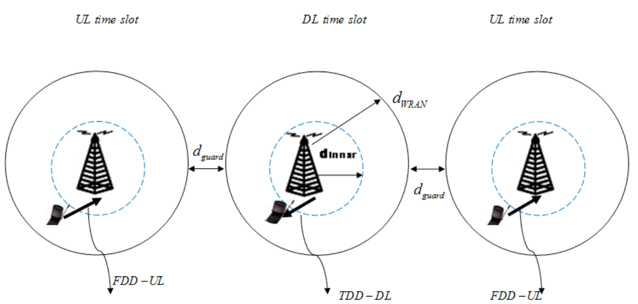

Figure 8: Interference Elimination in HDD System

Equation (3) shows the SIR that affects from the interference by due to the MSs located in the adjacent cell. When many MSs are located at the edge of the adjacent cell, the performance degrades. However, in the proposed system, for UL transmission, MSs located in the outer region of the cells operate by FDD mode and hence the MS-to-MS CTS interference is considerably reduced. This is illustrated in figure 8.

The overall SIR of the MS in HDD mode is given as

$$SIR_{HDD} = S_{BS\rightarrow MS} \Big/ I_{MS_1^i\rightarrow MS_2} + I_{MS_3^i\rightarrow MS_2} \quad (4)$$

Equation (4) shows the performance of the proposed scheme affected by MS located in inner region of adjacent cell. However the effect of interference from MSs located in the inner regions of the cell to the desired MS is neglected as the transmission power of MS located nearer the BS is always low. Comparing equations (3) and (4), the proposed HDD system produces better SIR performance.

Results: Performance Evaluation

1. Simulation Model and Parameters

Table 2 summarizes the simulation parameters. The free space path loss model is considered for simulation. In the simulation, 40 users per cell are taken considering the fact that this service is provided in the sparsely populated rural areas. In addition, it is consider that interference dominates compared to the noise in the system.

Table 2: Simulation Parameters

Parameter	Specifications
Number of users in the desired cell	40
Number of users in the adjacent cell	80
Number of desired BSs	1
Number of adjacent BSs	2
Multicarrier multiplexing	OFDM
Path loss model	Free space path loss model
Path loss exponent	4
User equipment transmit Power	1 W (30 dBm)
BS transmit power	16 W (42 dBm)
Radius of the cell	17.5 km

Figure 9 shows three cells with forty users in each cell. These forty users are randomly distributed in the cell so that some users are in the inner region (TDD) and some are in the outer region (FDD).

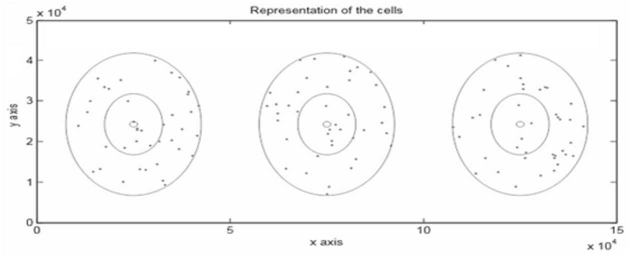

Figure 9: Representation of the Cells

In figure 10, the interference performance of the conventional TDD is compared with the proposed HDD system for the same transmit powers for 1000 iterations. The performance is obtained by computing the Cumulative distribution function (CDF) for various SIR trails.

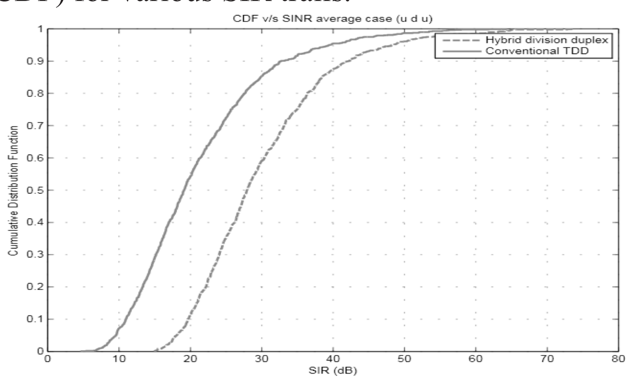

Figure 10: Performance of HDD and TDD Systems

The results are obtained for a conventional TDD system and a HDD system for an inner cell radius of 7.5 km. It can be inferred from figure 11 and table 3 that there is a performance improvement of 9 dB or 39 dBm in the HDD system when compared to the TDD system.

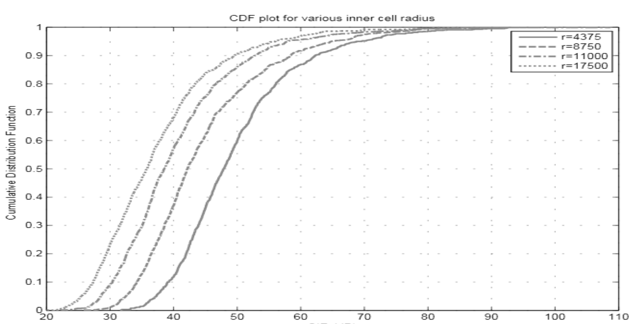

Figure 11: CDF v/s SIR for Varying inner Cell Radius

Table 3 summarizes the simulation results obtained during different iterations. It can be observed from table-3 that the best SIR performance of 34.0601 dB was obtained for the proposed HDD system whereas it was only 25.9875 dB for the TDD system. Also, the worst case performance observed for the proposed HDD system had a value of 18.2096 dB which is better when compared to the worst value of the traditional TDD system, which was obtained as 9.4689 dB. This reiterates our previous result that there is a 9 dB performance improvement.

Table 3: SIR Values of TDD and HDD System

SN	SIR of TDD System (dB)	SIR of HDD System (dB)	Performance Improvement (dB)
01	9.4968	18.2096	8.7128
02	14.7601	21.7156	6.9555
03	23.6467	34.0601	10.4134
04	9.4689	17.6122	8.1433
05	20.0039	27.7638	7.7599
06	25.1401	32.8527	7.7126
07	25.9875	35.1888	9.2013
08	15.1854	25.7885	10.6031
09	13.6543	22.7423	9.088
10	16.7411	25.3445	8.6034

2. Variation of the Inter-cell Distance

Inter cell distance increase the throughput of the system and also improves the spectral efficiency of the system. It can be inferred from figure 12 that as the distance between the cells increases, the performance is also improved.

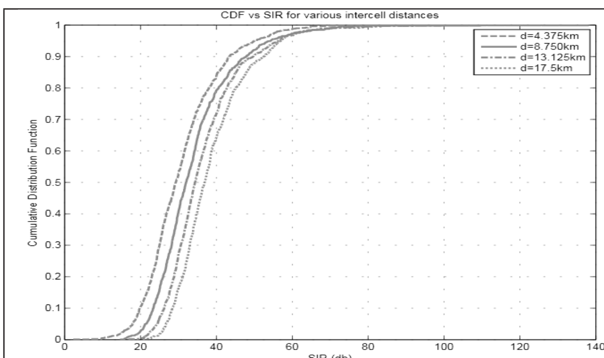

Figure 12: Inter Cell Distance Variation

In the conventional TDD system, a distance of r_c between the cells is maintained (where r_c is the radius of the cell in consideration). Having such a large inter-cell distance reduces the throughput of the system When HDD is applied to the system; the performance is similar to the TDD system when the distance is reduced to 0.5 r_c. This shows that the inter cell distance can be reduced to half without affecting the performance.

3. Variation in the Number of Users

The increase in number of users increases the interference in the system. Here, we consider by changing the number of users to 20 and 100 and compare the performance of two systems. The number of users was varied for both the TDD as well as HDD system. Then the CDF is plotted for both these cases. From figure 13 it can be inferred that the performance of the HDD system is better than that of the TDD system, showing an 8 dB improvement in the 20 users per cell case and 7 dB in the 100 users per cell case.

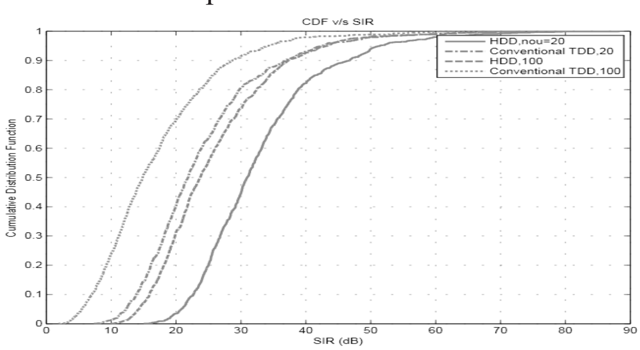

Figure 13: CDF v/s SIR for a Variable Number of Users

Furthermore, the performance of the HDD system in the 100 users per cell case is even better than the performance of the TDD system in the 20 users per cell case, this proves that HDD is a better scheme for the WRAN system. Moreover, increasing the number of users to 100 users from the standard 40 users per cell case resulted in a performance degradation of only 2 dB. Thus, the HDD system is not hugely affected by the increase in the number of users.

4. Single User in the Desired Cell

To analyse the worst case scenario, we consider a single user at the edge of the cell. As the user is located at the edge of the cell, it receives maximum interference from the users in the adjacent cells. A performance improvement of 9-10 dB is obtained in the system. Since the user is at the edge, the SIR is a small value when compared to the average cases. The improvement of SIR is similar to the previous result of the average case. Figure 14 gives the CDF comparison of the TDD and HDD systems for a single user.

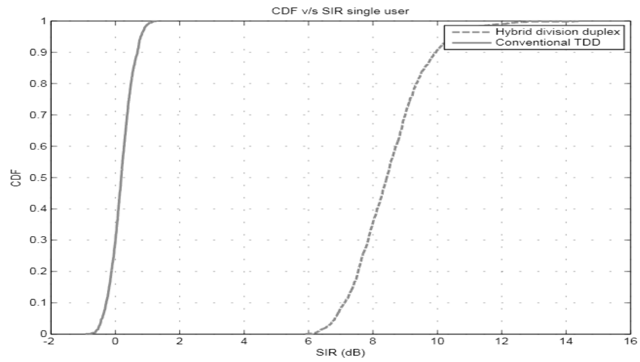

Figure 14: TDD v/s HDD for a Single User

A similar graph is plotted for the various inner cell radii. The results obtained adhere to our previous inference that the optimal radius should be between 8.75-11 km. Figure 15 gives a representation.

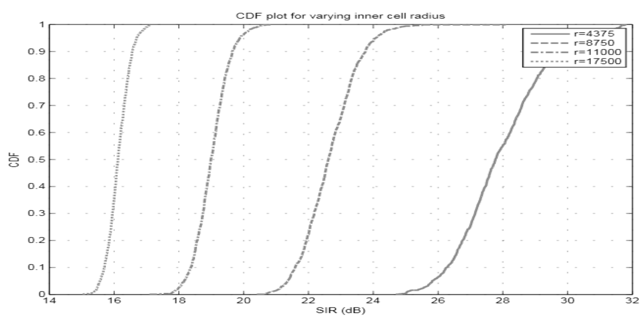

Figure 15: Variable Inner Cell Radiuses for a Single Cell

Case 2: Desired cell in UL/Adjacent cell in DL

Figure 16 illustrates the system model for case 2. In this case Cell 2 (desired cell) operates in FDD-UL mode and the adjacent cells operate in TDD-DL mode. SIR is proportional to signal power received from the BS of the desired cell. As these two signals are uncorrelated with each other, better SIR performance is achieved using the HDD system. In cases where the desired cell is in UL or DL and the other two cells are in UL and/or DL, conventional and proposed systems are free from cross time slot interferences. For ease of understanding, we omit these two cases from our analysis.

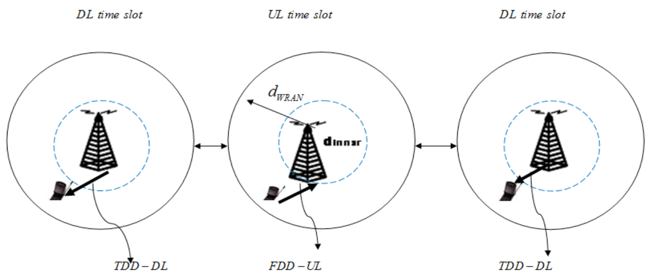

Figure 16: Desired Cell in UL/Adjacent Cell in DL in HDD System

Conclusion

In this paper, we proposed an IEEE 802.22 system that employs a new duplex scheme, namely, the HDD. This scheme enables a WRAN system to more flexibly and efficiently use its radio resources by exploiting the advantages of both the TDD and the FDD. In the proposed HDD system, the inner part of the cell operates by using TDD during both UL and DL modes whereas outer part operates using FDD in UL mode and TDD in DL mode. From the simulation results, it is found that the proposed scheme can achieve an improvement in SIR of 9 dB when compared to that of the TDD system. It is demonstrated that the proposed HDD system can effectively support an asymmetric traffic service as well as suppress MS-MS interference in multi-cell environment. It is also shown that the proposed HDD system outperforms the conventional TDD system in the context of outage probability, total throughput performance and SIR distribution. Therefore, it is expected that the proposed HDD-based system can be an attractive alternative to TDD duplex system in IEEE 802.22 and can play the role of a flexible wireless system enabler to build a cost-effective broadband access for rural areas.

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