Oil or Gas Station Parameter Monitoring for Industrial Application using IEEE 802.15.4 and MIMO based Visible Light Communication

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ABSTRACT
IEEE 802.11b & 802.15.4 operate at Industrial, Scientific & Medical (ISM) band of 2.4 GHz. In most of the industrial monitoring systems, the WLAN & WSN co-exist & dealing with such a heterogeneous system forming a single network becomes a sensitive issue. The IEEE 802.15.4 wireless sensor devices are very much vulnerable to interference with IEEE 802.11b WLAN standard devices. Though such a wireless communication makes the industrial monitoring simpler as compared to the wired system, IEEE 802.15.4 wireless sensor devices are very much vulnerable to interference with IEEE 802.11 WLAN standard devices because of which the WLAN devices nearby may affect the WSN data. In this paper we present an alternative MIMO based VLC system replacing the WLAN system for reducing data packet loss.

Index Terms: WLAN, WSN, throughput, PLR, MIMO, VLC, SNR

1. INTRODUCTION
In our previous paper[1] we presented the list of various parameters which are required for setting up & sustaining oil or gas station, such as, Temperature (Oil/Gas), Pressure (Oil/Gas), Vibration (Oil/Gas), Current (Oil), Level in storage tanks (Oil), Corrosion monitoring (Oil/Gas), Fire detection (Oil/Gas), Intrusion alarm (Oil/Gas), Leakage in underground supply pipelines (Oil/Gas), Leakage in tanks (Oil/Gas) etc. For effective monitoring of these parameters a wireless communication in general & wireless sensor network based devices is more suitable as compared to the wired system. Moreover such a system is easily expansible & more flexible.

In conventional Industrial Applications, the IEEE 802.11b & IEEE 802.15.4 are seen as affable because of their similar functionality & applications. The 802.11b uses the same unregulated radio signaling frequency (2.4 GHz) as the original 802.11 standard. The economical, inexpensive & low-power IEEE 802.15.4 operates in the same frequency band as the IEEE 802.11b which is the 2.4 GHz ISM band. The key issue being the coexistence of IEEE 802.11b & 802.15.4 conducting at the same frequency bandwidth, which gives rise to radio interference, leading to various disruptive effects such as data packet loss, transmission delay, jitter, loss of synchronization, etc.

Various co-existence models have been studied & presented in the past to improve upon the existing issue, however, the problems continue to exist. In this paper we present a completely new scheme for industrial application in oil or gas station. We propose an alternative to existing IEEE 802.11b with a MIMO based VLC system, which is a data communication system using visible light between 780- 375 nm. The use of VLC in place of IEEE 802.11b completely mitigates the interference issues in conjunction with lighting. The VLC system uses high brightness visible LEDs which can be modulated & encoded with data signals.

2. OVERVIEW OF THE SYSTEM
2.1 IEEE 802.15.4 WSN
IEEE 802.15.4 is a standard [2] economically designed for a low-cost and low-power Personal Area Network (PAN). It is one of the most conducive WSN standards in the present day market. Network is established between a PAN coordinator (Master) and a set of sensor nodes (Slave). The slave transmits short data packets to the master containing information gathered by the sensors. The IEEE 802.15.4 operates in the 2.4 GHz ISM band over 16 frequency channels each being 3 MHz in bandwidth. Similar to the IEEE 802.11b, IEEE 802.15.4 also exploits the CSMA/CA mechanism for media access control. However, instead of back-off period, IEEE 802.15.4 makes use of the Clear Channel Assessment (CCA) period. The contention window is also doubled whenever the channel is found busy for data transmission during CCA period. This is different from the IEEE 802.11b where the contention is doubled only when the ACK frame is not received.

2.2 IEEE 802.15.7 VLC
Visible Light Communication is a recent & advanced way of wireless communication using visible light. Typically, bright visible light LEDs serve as the transmitter & photodiodes as the receiver. In December 2011, The IEEE 802.15.7 Visible Light Communication Task Group completed draft 5c of a PHY and MAC standard for Visible Light Communications [3]. Task Group 7 also chartered to write standards for free-space optical communication using visible light. A more elaborate description of the VLC scheme used in our case is being discussed in section IV.

Moreover, Visible light communication (VLC) has various advantages over other competing radio communication technologies [4]. As for example, Visible light spectrum is available for communication in the frequencies above 3THz which is unregulated by the Radio Regulation Law. Also, Visible light usually poses no health hazards to human body and eyes, while simultaneously transmitting data.

3. COMPARATIVE STUDY OF VARIOUS MODELS
In existing WSN- WLAN based models, the coexistence issues are mainly of two types,

- WLAN operation with WSN interference.
- WSN operation with WLAN interference.

According to [5], [6] and [7], IEEE 802.15.4 has very little effect on the performance of IEEE 802.11b but the reverse is not true.

In [1] a model was presented, segregating monitoring data which require continuous processing & those of which do not require continuous processing.

In [1], the model was presented based on the power aspects, corresponding timing aspects & the Packet Loss Ratio (PLR) which is the ratio between the number of lost packets & the number of transmitted packets of IEEE 802.11b and IEEE 802.15.4. The corresponding throughput values have been calculated by taking into account the T_{poll} value which is the polling time dedicated to each sensor node and the duty cycle λ_{wlan} which is defined as $\lambda_{wlan} = \tau_{wlan}/T_{pck}$ where τ_{wlan} is the time interval of the transmitted packet and T_{pck} is the time interval between two packets. However, the problems of data loss due to interference persisted & could not be completely eliminated.

In 2010, Siemens researchers transmitted wireless data using white LEDs for a range of 5 m at a speed of 500 megabits per second & suggested that Visible Light Communication could be a valuable substitution to the existing WLAN technology [8].

4. SYSTEM DESCRIPTION

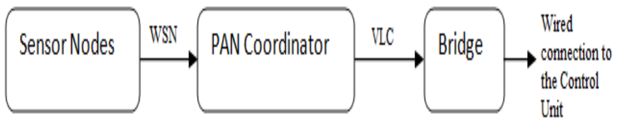

Fig.1. System Overview

Fig. 1 describes the System Overview of our proposed model. The data from the various monitoring sensors are being transmitted by IEEE 802.15.4 WSN standard, which are then received at the modulation stage. From the modulation stage, the Pre-coding MIMO – Indoor Visible Light Communication takes over as shown in Fig. 2. However, it is to be noted that the WSN PAN coordinator & the bridge lie within the line of sight so that the optical signal propagates to the bridge receiver directly.

OOK modulation scheme is being used in this particular transmitter setup. It is the simplest and most commonly used modulation scheme that represents data both in the presence and in the absence of a carrier wave. This scheme is used in the Industrial, Scientific and Medical (ISM) band which is the same frequency band in which the IEEE 802.15.4 WSN works. Moreover it is also suitable for optical communication.

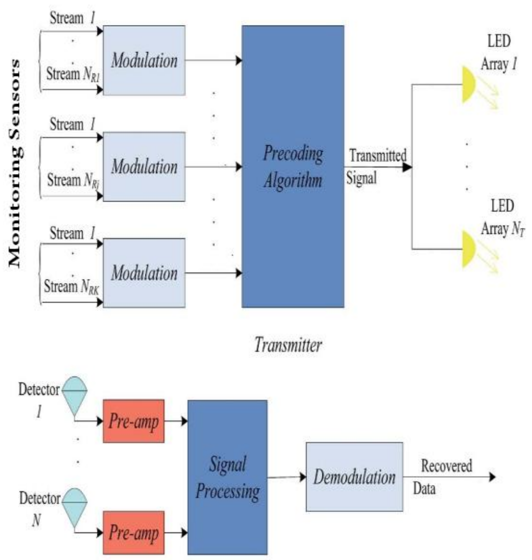

Fig. 2. Sub system

The performance of the pre-coding MIMO system for Visible Light Communication has been investigated [9]. The bandwidth of the white LED used for the Visible Light communication is to several MHz [10]. The optimum luminance for Visible Light Communication system should be 300-1500 lx [11], hence multiple LED sources are commonly employed. Therefore, to improve data rate, for a very high signal to noise ratio (SNR), multiple inputs & multiple output (MIMO) technique appears attractive.

The difficulty of separation of the transmitted data of various user terminals or sensors is mitigated by Block Diagonalization (BD) Pre-coding Algorithm. The BD Algorithm is adopted in the transmitter by pre-processing the data of each user terminal. This reduces the complexity as well as the power consumption. [9] Derived the corresponding solution by utilizing optical detectors with different field of view (FOV), focusing on the BER & SNR performance.

[9] Describes the Block Diagonalization (BD) algorithm based MIMO- VLC system. Considering the sensors as the users, the multiuser interference is eliminated by Block Diagonalization (BD) algorithm in the transmitter so that receiving end, the data is completely restored, with minimum complexities as far as processing is concerned.

The BD algorithm pre-processes each user with a pre-coding matrix,

F_j (j=1 to k) such that, $H_{i*}F_j = 0$ for all $i \neq j$, $i >= 1$, $j >= k$. Where, k= Number of user terminal & H_i= Channel Matrix.

Let the modulated On Off Keying (OOK) is given by u(t). After BD Pre-coding, the signal vector is given by:

$$f(t) = \sum_{j=1}^{k} \left(F_j u_j(\mathrm{t})\right)$$

Therefore, the output signal at the output of the LED array is given by,

$$x(t) = \sum_{j=1}^{LEDs} (\mathrm{P}_{LED}\ (1 + M_{\mathrm{I}}\mathrm{f(t)})$$

Where M_I is modulation index; LEDs is the number of LED per array; P_{LED} is single LED chip's power.

At the receiving end, the signal is received at the detector. Post which, the output of pre-amplifier, signals is multiplied with Hermitian transpose of matrix. Finally the data can be restored after demodulation without the much complicated processing at the Bridge. From the Bridge, via a wired connection, the data is finally sent to the control unit where the various Oil or Gas Station parameters are being processed & the necessary alarm signal is generated.

5. SYSTEM HIGHLIGHTS

The setup of the system using WSN & MIMO based VLC system is shown in Fig. 3. The parameters of the system [9] as shown in table 1 were used to simulate the SNR characteristics.

Fig. 4 shows the relation between single LED power and SNR of a single user or sensor when the FOV of the terminal is kept constant at 70 degree.

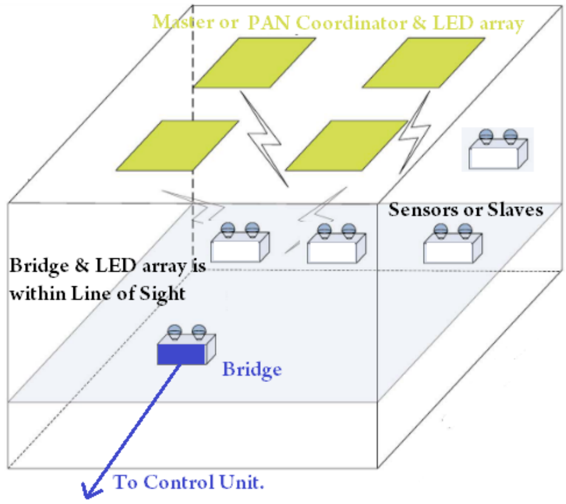

Fig. 3. The Setup

Table 1: System Parameters

Parameters	Values	Parameters	Values
Room size ($W \times L \times H$)	$5m \times 5m \times 3m$	PD Responsivity	$0.4\ A/W$
Detector physical area of a PD	$1.0\ cm^2$	Receiver pitch	$0.1\ m$
Number of LEDs per array	3600 (60 x 60)	Gain of optical filter	1.0
Center luminous intensity	$0.73\ cd$	Size of LED array	$0.59m \times 0.59m$
Background light current	$5100\ \mu A$	Modulation Index	0.2
Refractive index n	1.5	LED pitch	$0.01\ m$
Transmitter semi-angle	$60\ deg$	Data Rate	$100\ Mbit/s$

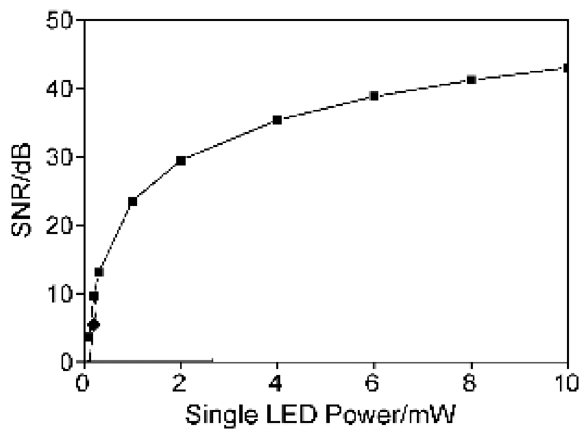

Fig.4. SNR – LED power characteristics

6. CONCLUSION

In this paper, we successfully proposed a system for Oil or Gas Station Parameter monitoring and management control of the various parameters based on the IEEE 802.15.4 WSN & the MIMO based VLC System, which incorporated BD algorithm which makes the separation of data from various sensor terminals easier. The VLC system substitutes the IEEE 802.11b WLAN so that interference issues pertaining to IEEE 802.11b & IEEE 802.15.4 are mitigated.

7. REFERENCES

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