Communication System for Underground Mines Using Li-Fi 5G Technology

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Abstract **-In this paper presents an overview of Li-Fi 5G communication system for underground mines for passing emergency information to the worker under risk conditions. The system includes light/voice signal can be used for data transmission. Recent tragic events and mine emergencies at the Alma, Saga, queered and mines have highlighted the need for reliable communications between inside and outside mines. Nowadays, the most of the mines using radio wave communication for their information exchange. While doing that the proper data communication through radio wave is not possible at the bottom of underground mines because of irregular data propagation and limited frequency range 3 kHz-300 GHz. So, Wi-Fi technology is replaced by Li-Fi 5G technologies, the basic idea behind this technology is visible light communication. According to this technology, it has covered wide range of frequency (430-790) THZ and fast data transmission when compared to Wi-Fi.**

Keywords-Wireless-fidelity (Wi-Fi), light-fidelity (Li-Fi) light emitting diode (LED), Line of sight (LOS), visible light communication (VLC)

I. INTRODUCTION

Visible Light Communication is the activity related to the transmission of signal (data) for the sake of information exchange. In underground mines communication is the carrying need both from safety and productivity point of view. Keeping pace with the business market and lifestyle of the miners, in which transmission deals with the amount and speed of the data through the transmitting medium. This seems very simple as a huge amount of data can be sent at a very high data rate through visible light communication. In this Li-Fi process the theoretical speed up to 1GB per second.

II. TYPES OF COMMUNICATION SYSTEM FOR UNDERGROUNDS MINE

Conventional systems or the wired system is composed of magneto phones, paging phones, voice powered phones etc magneto phones are the oldest crack rays phone of 20th century operated by DC batteries and AC signals paging phones are party line wired phones for voice communication with no tracking capability. TTE or through the earth system is a well known system providing alarming, tracking and messaging with the help of loop antennas on surface of mine which transmit low frequency signal to receivers, integrated into cap lamps. Whereas wireless network deals with the Wi-Fi (IEEE 802.11), Bluetooth (IEEE 802.15) and Wimax technologies and the new trend is the visible light communication is LI-FI (IEEE 802.15) the operating speed of the Li-Fi is greater than that of the Wi-Fi with in nanosecond the information is transmitter to the receiver section.

Fig 1: Underground Mines

2.1 UG Coal Mine Communication System Design

Before any new communication system is installed in a mine the electrical noise environment both surface and UG should be measured, documented and analysed. Next signal propagation measurements should be performed documented and analysed candidate technology should be reviewed, tested and evaluated older mine communications system should be technically reviewed and updated accordingly.

2.2 Electromagnetic interference/Noise

Analysis and design of radio communication system requires knowledge of atmospheric. Noise models also the performance of any electronic communication system is highly dependent on the electromagnetic (EM) noise of the environment in which it will be used. The selection of candidate operational/emergency EM mine communication and location system should therefore occur after Emi measurements are made. If there were no natural or manmade electrical noise interference TTE receives could be extremely sensitive and transmitter could be very low power. Through recent events have shown that most normal communications system can fail during disasters they still can play a significant role for normal everyday use. Particular emphasis will be put on radios since this technology after the miners the most flexibility and instantaneous communications. The present concept using radio in a mine is called “WI-FI” requires strategically

placed wireless repeaters. Interestingly these systems are digital which opens up a new realm of possibilities, Including simultaneously delivery of voice (VOIP), data and video over the link. They should penetrate through LED lamp, There were also been a merging of technologies which combine leaky feeder ethernet and Wi-Fi.

III. IEEE 802.15.4 OVERVIEW

The point of service (POS) may be extended beyond 10m but this requires additional energy to operate. It also allows two types of topologies such as a simple one hop star or a self configuring peer-to-peer network to be established. In terms of wireless links, 802.15.4 operates in three license free industrial scientific medical (ISM) frequency bands, i.e. data rates of 250 kbps in the 2.4 GHz band, 40 kbps in the 915MHz band, and 20 kbps in the 868 MHz band. The first band has 16 channels while the second has 10. The former is desired in this paper because it can take on the role of a router that enables peer-to-peer communication.

In terms of addressing, the protocol assumes the use of either 16bit short or extended 64-bit IEEE addresses. The latter is available in all devices by default and is commonly known as physical (MAC) address while the previous is allocated by the PAN coordinator which the device is associated with. There are two categories of devices in 802.15.4. One of them is called full-function device (FFD) while the other is reduced-function device (RFD). RFD is crude device supporting simple application such as a switch or sensor.

The 802.15.4 standard defines physical (PHY) and medium access control (MAC) layer protocols for supporting relatively simple sensor devices that consume minimal power and operate in an area of 10m or less. It is usually controlled by FFD device. RFDs can be used to communicate among themselves and with FFDs. The latter was allocated one channel. Though only one channel is used at a time, the additional channels allow the flexibility of switching to another in case the existing becomes not conducive. In the following section we shall describe briefly the IEEE 802.15.4 standard particularly the MAC and PHY layer.

3.1 PHY Layer

These are the PHY data service and the PHY management service. As part of 802.15.4 effort in preserving energy, the radio transceiver can be turned off if inactive (not receiving or transmitting). The PHY layer provides an interface between the MAC sub layer and the physical radio channel. It provides two services, accessed through two service access points (SAPs). A channel is considered busy if the activity levels detected exceed certain threshold value. Another important assessment is link quality. If a particular channel is not feasible, there are 26 other channels available under 802.15.4 to be selected. Upper layers protocols (MAC and network) depend on this information before deciding on using a particular channel because external interferences such as noise and electromagnetic signal could affect the network performance.

3.2 MAC Layer

In our approach, we adopt beaconless mode which implies un slotted CSMA/CA mechanism. Without the RTS/CTS handshake, it would appear to encourage packet collisions due to hidden nodes. Nodes are considered hidden if they are out of signal range of each other. This mechanism evaluates the channel and allows data packets to be transmitted if the condition is suitable (free of activities). For this mode, the PAN coordinator is responsible of handling only device association/disassociation and (short) address allocation in case the 64-bit IEEE addressing is not used. This layer provides an interface between upper layers and the PHY layer. The CSMA/CA protocol is an important mechanism for channel access but does not include the RTS/CTS handshake, considering low data rate adopted in 802.15.4. It handles channel access, link management, frame validation, security, and nodes synchronization.

IV. PROBLEMS IN PRESENT WI-FI TECHNOLOGY

The current Wi-Fi network is not perfect. There are many problems in the aspects; the current standards for Wi-Fi are not provided support for these problems.

4.1 Security

Because the transmission process of wireless signal is completely exposed to the air, it is more vulnerable than wired network to be hacked. If no proper security strategies, the network will face a larger risk. At the same time, "rub network" phenomena is very common in daily life. It seriously affects the speed and stability of the wireless network.

4.2 Roaming Switch

When we construct the wireless LAN, a large number of APs are deployed in order to cover larger-scale signals. When people move in the LAN, the terminals need to be switched among these AP. The traditional switch idea used by Wi-Fi network is “first cut then connect". That is when the transition process is initiated; the workstation firstly cuts from the current AP, and then begins the normal switching process. This may lead to the larger delay (>300ms), which affects the performance of mobile applications

4.3 Stability

The wireless networks are easy to be disturbed by other signals around them due to the openness of the wireless channel. This results in the unsteadiness of Wi-Fi signals so as to effect on the quality of services. The stability is improved in the form of every in process and in located through in form.

The main factors influenced on the stability of wireless network are microwave over 2.4GHz Cordless Phone and Mutual interference among the WLAN networks.

V. DESIGN OF LIGHTING SYSTEM FOR MINES

Many startling breakthroughs have been made in lighting knowledge since Edison’s discovery, including some with applications in underground mines. The environment of an underground coal mine is a dynamic one that includes dust,

confined spaces, low reflective surfaces and low visual contrasts. Lighting is critical to miners since they depend heavily on visual cues to spot fall of ground, pinning and striking and slipping and tripping hazards. Consequently, illumination greatly affects miners' ability to perform their jobs safely. Typically, a miners' cap lamp is the primary and most important source of light for underground coal mines. Lighting plays a critical role for miners as they visually inspect the mine roof, ribs, back and floor for slip, trip and fall hazards. Objects associated with these hazards are typically of very low contrast and reflectivity.

Secondly, there are age-related factors that require a better quality of light. Diminished night vision is one of the most common problems experienced by older people because there are changes in the eye that include decreased pupil size, cloudier lens and fewer rod photo receptors that are very sensitive to light. Designing of good lighting systems for underground coal mines is not an easy task because of the prevailing unique environment and nature of work encountered. Designing of Lighting System on the surface at different levels of light source from the surface each has inherent advantages and disadvantages.

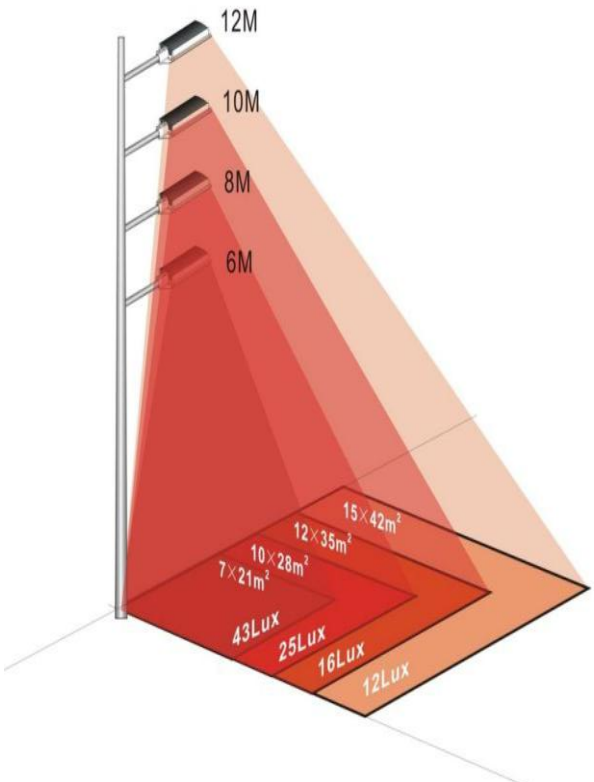

Fig 2: Designing of Lighting System on the surface

Recent Advancement in lighting technology replaces all the defects and shortcomings stated above is met with LED lighting systems. In table1 shows Comparison of cost and power of incandescent bulb, CFL and LED Lighting systems. Shows various feature of incandescent bulb, CFL and LED Lighting systems.

Table 1
Comparison of cost and power of incandescent bulb, CFL and LED lighting systems

Lux	Incandescent bulb	DC/ Power Source	Cost of Power/Day (AC)	Colour rendition	CFL	DC/, Power Source	Cost of Power/ Day (AC)	Colour rendition	LED	DC/ , Power Source	Cost of Power/ Day (AC)	Colour rendition
455	40	Yes	4.32	Good	10	Yes	1.08	Good	3	Yes	0.324	Excellent
810	60	Yes	6.48	Good	14	Yes	1.512	Good	5	Yes	0.54	Excellent
1200	70	Yes	7.56	Good	17	Yes	1.836	Good	8	Yes	0.864	Excellent
1500	100	Yes with limitations	10.8	Average	25	Yes with limitations	2.7	Good	14	Yes	1.512	Excellent
2650	150	Yes with limitations	16.2	Average	30	Yes with limitations	3.24	Good	20	Yes	2.16	Excellent
3000	180	Not advised	19.44	Fair	45	Yes with limitations	4.86	Good	29	Yes	3.132	Excellent
3600	200	Not advised	21.6	Fair	56	Yes with limitations	6.048	Good	30	Yes	3.24	Excellent
4000	250	Not advised	27	Fair	65	Yes with limitations	7.02	Good	40	Yes	4.32	Excellent

5.1 Light fidelity:

Li-Fi, or light fidelity, refers to 5Gvisible light communication systems using light from light-emitting diodes (LEDs) as a medium to deliver networked, mobile, high-speed communication in a similar manner as Wi-Fi. Li-Fi could lead to the Internet of Things, which is everything electronic being connected to the internet, with the LED lights on the electronics being used as internet access points. The Li-Fi market is projected to have a compound annual growth rate of 82% from 2013 to 2018 and to be worth over $6 billion per year by 2018 Visible light communications (VLC) signals work by switching bulbs on and off within nanoseconds, which is too quickly to be noticed by the human eye. Although Li-Fi bulbs would have to be kept on to transmit data, the bulbs could be dimmed to the point that they were not visible to humans and yet still functional. The light waves cannot penetrate walls which makes a much shorter range, though more secure from hacking, relative to Wi-Fi. Direct line of sight isn't necessary for Li-Fi to transmit signal and light reflected off of the walls can achieve 70 Mbps.

Li-Fi has the advantage of being able to be used in electromagnetic sensitive areas such as in aircraft cabins, hospitals and nuclear power plants without causing electromagnetic interference. Both Wi-Fi and Li-Fi transmit data over the electromagnetic spectrum, but whereas Wi-Fi utilises radio waves, Li-Fi uses visible light. While the US Federal Communications Commission has warned of a potential spectrum crisis because Wi-Fi is close to full capacity, Li-Fi has almost no limitations on capacity. The visible light spectrum is 10,000 times larger than the entire radio frequency spectrum. Researchers have reached data rates of over 10 Gbps, which is more than 250 times faster

than superfast broadband. Li-Fi is expected to be ten times cheaper and more environmentally friendly than Wi-Fi. Short range, low reliability and high installation costs are the potential downsides.

Li-Fi is a new class of high intensity light source of solid state design bringing clean lighting solutions to general and specialty lighting. With energy efficiency, long useful lifetime, full spectrum and dimming, Li-Fi lighting applications work better compared to conventional approaches. This technology brief describes the general construction of Li-Fi lighting systems and the basic technology building blocks behind their function.

5.1.1 Li-Fi construction

The Li-Fi product consists of 4 primary sub-assemblies:

- Bulb
- RF power amplifier circuit (PA)
- Printed circuit board (PCB)
- Enclosure

The PCB controls the electrical inputs and outputs of the lamp and houses the microcontroller used to manage different lamp functions. An RF (radio-frequency) signal is generated by the solid-state PA and is guided into an electric field about the bulb. The high concentration of energy in the electric field vaporizes the contents of the bulb to a plasma state at the bulb's centre; this controlled plasma generates an intense source of light. All of these subassemblies are contained in an aluminium enclosure.

5.1.2 Function of the Bulb Sub-Assembly

At the heart of Li-Fi is the bulb sub-assembly where a sealed bulb is embedded in a dielectric material. This design is more reliable than conventional light sources that insert degradable electrodes into the bulb. The dielectric material serves two purposes; first as a waveguide for the RF energy transmitted by the PA and second as an electric field concentrator that focuses energy in the bulb. The energy from the electric field rapidly heats the material in the bulb to a plasma state that emits light of high intensity and full spectrum.

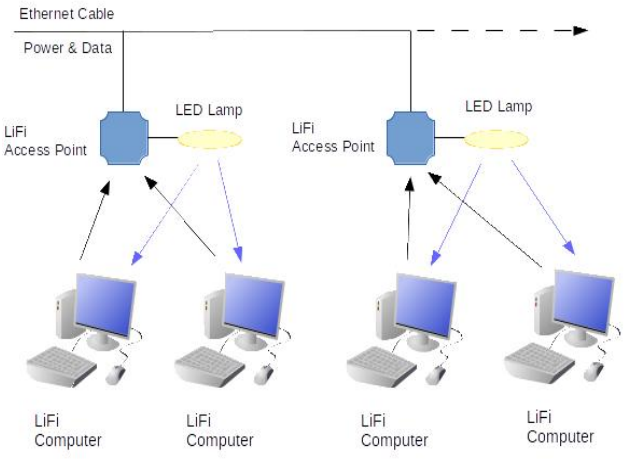

Fig 3: Li-Fi Process through LED Lamp

Li-Fi is a new way to establish wireless communication links using the Led lighting networks. The Li-Fi protocols are defined by the international standard IEEE 802.15 established since 2011 by the IEEE comity. This is the same comity that has defined previously the Ethernet 802.3 and Wi-Fi 802.11 standards. For numerous specialists, Li-Fi is a major breakthrough technology for the mobile Internet community and for the connected objects domain. After more than 4 years of scientific research at the University of Versailles, OLEDCOMM is the first European company that start to commercialize Li-Fi communication solutions a worldwide level.

VI. PROPOSED METHOD

The main objective of the proposed method is to improve the effective data transmission from the base station to receiving station in the underground mines. At present, the Wi-Fi technology has been used for information exchange along with large delay which affects the data transmitting speed and loss of the data. This problem can be overcome by proposed method and give effective communication between sender and receiver. Here, working procedure is same as that of Wi-Fi but instead of radio wave the light wave is used from the lighting arrangement in the underground mine and power consumption of these light also very low. The lightning system consists of the Li-Fi circuit driver to sense the signal from the base station through the light the photo detector in the device capture the signal and passes the data to the monitoring section of the underground mines.

By using the Li-Fi process the transferring speed of the information has been increased to the monitoring sections. In worldwide, there are around few billion light bulbs used in mines, they just need to be replaced with LED ones that transmit data," says Haas. "We reckon VLC is a factor of ten cheaper than Wi-Fi." Because it uses light rather than radio-frequency signals, VLC could be used safely in aircraft, integrated into medical devices and hospitals where Wi-Fi is banned, or even underwater, where Wi-Fi doesn't work at all. He explained, "Very simple, if the LED is on, you transmit a digital 1, if it's off you transmit a 0. The LEDs can be switched on and off very quickly, which gives nice opportunities for transmitting data. The server process listens on a particular port on the server machine. When the server receives an HTTP request, it parses the URL and finds the file number. It then chooses a random number (according to a particular distribution function) as the size of the HTML document, and forks a child process. The child process sleeps for a specified number of seconds, then constructs an array of the specified size, fills the array with string "aaa[file number]", replies to the HTTP request with the array attached to a pre-filled response header, and then exits and it connected an RF power amplifier is a type of electronic amplifier used to convert a low-power radio-frequency signal into a larger signal of significant power, typically for driving the antenna of a transmitter.

It is usually optimized to have high efficiency, high output Power (P1dB) compression, good return loss on the input and output, good gain, and optimum heat dissipation.

Light-emitting diodes (LEDs)—small colored lights available in any electronics store—are ubiquitous in modern society. They are the indicator lights on our stereos, automobile dashboards, and microwave ovens. Light bulbs are really just wires attached to a source of energy. They emit light because the wire heats up and gives off some of its heat energy in the form of light. An LED, on` the other hand, emits light by electronic excitation rather than heat generation. Diodes are electrical valves that allow electrical current to flow in only one direction, just as a one-way valve might in a water pipe. When the valve is "on," electrons move from a region of high electronic density to a region of low electronic density. This movement of electrons is accompanied by the emission of light and the more electrons that get passed across the boundary between layers, known as a junction, the brighter the light. The advantages of the LED over the light bulb for applications requiring a small light source encouraged manufacturers like Texas Instruments

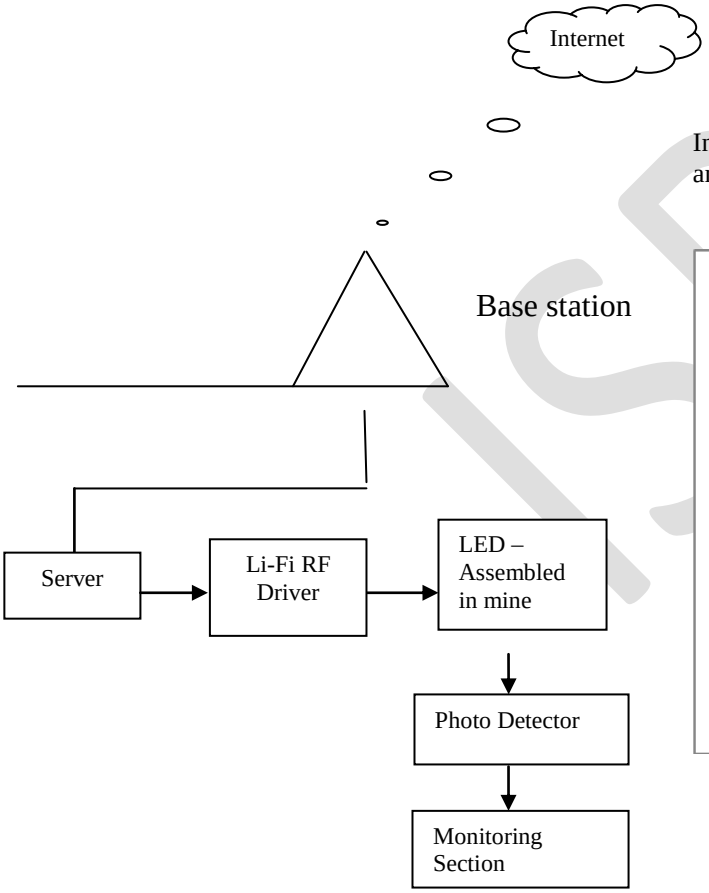

Fig 4: Working Process

An assembly line is a manufacturing process (most of the time called a progressive assembly) in which parts (usually interchangeable parts) are added as the semi-finished assembly moves from work station to work station where the parts are added in sequence until the final assembly is produced. By mechanically moving the parts to the assembly work and moving the semi-finished assembly from work station to work station and A transmitting antenna is an electrical device which converts electric power into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an oscillating radio frequency electric current to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals, that is applied to a receiver to be amplified

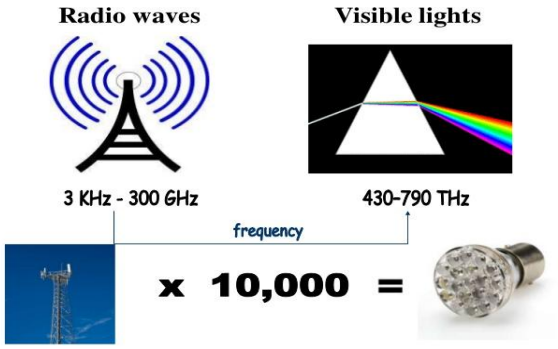

Fig 5: Difference in frequency range

In the below graph we can estimate the comparison on Li-Fi and Wi-Fi

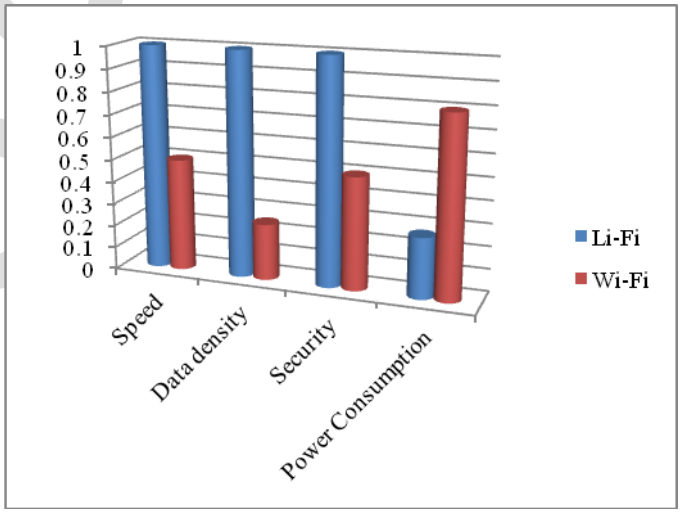

Fig 6: Comparison of Li-Fi VS Wi-Fi

CONCLUSIONS

Wi-Fi is certainly not useless, but it has certain inherent limits (frequency range 3 kHz-300 GHz) for the technology. Li-Fi may not be able to replace conventional radios altogether, but it could turbo change the development of wireless monitoring section in mine and make it easier to throw a wireless signal across an entire underground mines. At present, finding the ideal position for a wireless router is something of a divine art. If the signal could be inside an underground mines. At present, finding the ideal position for a wireless router is something of a divine art. If the signal could be passed via VLC from Point A to Point B inside an underground mine, small local routers at both points could create local fields with less chance of overlapping and

interfering with each other. Large scale areas that are saturated with radio signals or that doesn't permit them for security reasons could use Li-Fi as an alternate high-speed wireless network and power consumption solution.

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