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Design and Attainment Assessment of Different Protocols for Smart Industry to Observe and Control Gas Leakage Employing WSN

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Abstract*: Harmful gases leaking from the equipment that are installed in the industries cause huge loss of lives of the workers as well as people living nearby the industries. The main causes for the gas leakage are poorly maintained machines, leaky storage tanks. So, focusing on the concentration of harmful toxic gases, a virtual analysis has done using QualNet 6.1. Different numbers of nodes have dropped randomly in different terrain areas. Three protocols LRWPAN, LRWPAND, LRWPANDMC have been used to virtually analyze the gas leakage scenario. These sensors detect the gases when the leakage is near about or more than the limit. At each time some nodes will be in sleep mode and others will be in active mode, this mechanism will increase the lifetime of the battery, as changing battery frequently will not be possible especially in remote areas. The crucial profit of this paper is to show the network performance which is simulated with a sink node receiving packets for different time duration and at different frequencies. The idea is to find out the optimal and efficient network for fast information flow with 50, 100, 300 nodes. The terrain area of the network is 100×50 m^2, 100×100 m^2, 500×500 m^2 with the communication range of 10 m. The routing protocols implemented are Low-Rate Personal Area Network (LRPAN), Low-Rate Personal Area Network with Drift (LRPAND) and Low-Rate Personal Area Network with Drift and Multi-Channel. This paper has evaluated and analyzed the influence of packet flow at the different frequencies of 2.425, 2.450, 2.475 and 2.480 GHz. It is analyzed that performance of each protocol has varied significantly for different number of nodes. The performance of the network is improved by the different frequencies instead of 2.4 GHZ frequency. The parameters average end to end delay (seconds), jitter (seconds), throughput (bits per second) and network lifetime (hours) for different protocols such as LRPAN, LRPAND and LRPANDMC for different numbers of nodes 50, 100 and 300 are evaluated and compared. The optimum results are obtained by the LRPANDMC in the simulation process. Evaluation and analysis of the influence of different protocols on different number of nodes for different parameters has been done to determine most effective protocol. This type of network can be used in oil and gas industries, petroleum industries at remote areas where there are high chances of gas leakage incidents. The aim is to provide information in real-time scenario virtually.

Keywords*: Gas leakage, IEEE 802.15.4, ZigBee, LRWPAN, LRWPAND, LRWPANDMC, QualNet 6.1, Wireless Sensor Network.

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I. INTRODUCTION

The industrial disaster is the most dangerous calamity which could harm the present as well as future generations. Loss of lives and property greatly increases because of man-made and natural calamity, these calamity increases the risk of an industrial disaster sometimes. The range of area till where disaster is felt is always vulnerable to dangers. Extreme explosions inside the industries will be caused due to these disasters which will tremendously increase the number of lives lost. Operations that are carried out to rescue workers in such an immensely hazardous and erratic environment can be risky as these operations could be secondary disasters. In WSN, the data is processed and travel through the communicating components with the help of battery-operated sensors devices. Concerning the security of sensor network, sensors are setup in controlled and uncontrolled surroundings. Information gathering from the real world is the essential part of WSN. ZigBee is a standard for wireless technology that runs on IEEE 802.15.4 specifications and is accessible universally, as for the personal area network, digital radio signals are used which consume less power. Its feature is the secure communication which is possible with the use of 128-bit cryptographic keys consists of symmetric keys, in which same key is shared by both the receiver and the sender. The keys which are used are either transported by trust center within network and these keys are pre-installed or entrenched between trust center and the device during no transportation. The three levels of simulation study in QualNet are:

- Models for simulation are generated depending on domain and utilization of parameters.
- Collecting outcomes which are based on constructed parameters.
- Deduction of results and inference is done by the analysis of these parameters.

With the application of different properties like end-to-end delay, average jitter, throughput, contrasting of ZigBee routing protocol of Ad-Hoc On-Demand Vector (AODV), Dynamic Source Routing (DSR), Dynamic MANET [1].

II. LITERATURE REVIEW

ZigBee technology is the recent, believable and cost-efficient on which WSN system is build up.

Hardware and software are implemented based on TinyOS in which the combination of MAC layer and ZigBee layer with nodes and ZigBee parts is applied [2].

An alarm for disaster alertness is designed with powerful working which would blow before the disaster happen this reduces the after effects of disaster and respond immediately [3]. Many system models are designed to check the efficiency of wireless mesh network on them in multiple conditions. When the cellular network breaks down the best protocol among Ad-hoc on-demand distance vector (AODV), Zone routing protocol and Dynamic source routing protocol (DSR) is chosen after their comparison on various parameter [4]. Sensors are spread in the farm to monitor the temperature and moisture of the soil. Each sensor is engaged in sending the information as human involvement for this is not enough. An LDR is used to check whether proper lightning at that place is available or not [5]. In this paper using the ZigBee communication and flood detection functionalities, a flood monitoring system is designed for distributed substations in low-lying area [6]. Detailing the design of ZigBee MAC layer protocol in the 4 ways: the package of the MAC frame structure, avoiding the conflict of channel access, the realization of synchronization between devices, send and receive of MAC frame. So, it could implement the effective access to the channel by using the physical layer interface function. Finally, the related function test of MAC layer is given, the results show that the system is running properly and stable [7]. Significance of the operation of the MAC layer depends on the various approaches to operate with ZigBee devices and its various layers. The ZigBee devices can operate in either beacon or non-beacon mode. Beacon mode is meant for energy saving mode that is it is used when more power saving is required with low throughput whereas non beacon mode is meant for high throughput and power saving is not a big concern. As the network size expands the performance of beacon mode decreases but has no changes on the working capacity of non-beacon mode. Thus, ZigBee mode is the major concern depending on the network range [8]. Time to time detecting the gas leakage and uploading the data to the monitoring center is performed by the Gas Leakage Monitoring system which is self-organized. The sensor nodes involved in this will provide real time information of concentration of flammable gases. As soon as the gas concentration reaches beyond the threshold value, the loud and visual alarm will be blown and an alert information is displayed on the computer to the staff so that quick actions could be taken [9]. Toxic gas leak monitoring and alarm system has been developed to fulfill the need of real time monitoring and alarm of the petrochemical plant using WSN. Hardware is designed to meet the functional requirement based on ZigBee protocol stack. System has stable performance, fast response and wide coverage to create good condition reliable alarm and a fast processing alarming system [10]. In order to find out the suitable protocol set for the proposed application, this paper describes and published about the methodology and results of experimentation in the network layer of IEEE standard 802.15.4 ZigBee protocol stack with different types of On-Demand Distance vector routing protocols viz., AODV, DYMO and DSR, while keeping the MAC layer protocol Sensor MAC (SMAC) unchanged. DSR defeats the AODV and DYMO [11]. In this paper, evaluate the performance of AODV protocol with star topology using different mobility models. Performance analysis and evaluation has been done on the different metrics like jitter, throughput, packets dropped, End to End delay, energy consumption in different processing modes and percentage of time consumed in different processing modes. Simulation has been done on the QualNet 5.0; the analysis shows variation in the performance on different metrics. When CBR traffic is used for data transmission broad changes had been observed on the metric performance like jitter, throughput, end-to-end delay and energy. Group based mobility is more efficient for data transmission, percentage of average packet drop and energy consumption is less as compared to without mobility [12]. Gas leakage monitoring system for a hazardous environment is introduced to monitor and repair the work comparing with those on the basis of hand held detection equipment provides abundant information of field environment, detecting gas more accurately, reducing fault detection and making rapid response to gas leakage risks. WSN technology is applied to monitoring environment data to gas. The system can detect the methane concentration, temperature, humidity and the speed and direction of the wind in real time and therefore greatly improves the practicality of the system [13]. A hardware and software design for Wireless Sensor Network is given for the realization of gas monitoring via power cable and early warning is done with the combination of Wireless Sensor Network and 4G LTE. ZigBee nodes have the advantages of low cost, low power consumption and large network capacity. At the same time, 4G LTE module has the advantages of always on-line, free handover, high transmission rate, flexible and cheap billing, so the system has a very wide range of application value [14]. Multi-radio multi-channel approach was chosen as it has many advantages as compared to single-radio multi-channel. Not only did it have to work, but optimizations had to be done to get a significant increase in performance compared to the classical single-radio single-channel setup. The various parameters like throughput, jitter and packet receive ratio of the wireless mesh networks can be upgraded extremely by using multi-radio multi-channel approach instead of using single-radio multi-channel approach with different data traffic like CBR, VBR, VoIP etc. [15]. The stability of existing electric grid can be improved by merging the new grid technologies with it. Combining the recent grid technologies with the current electric grid improvise the stabilization condition of electric grid. The performance analysis of ZigBee simulation characterizes the IEEE 802.15.4 as best for low-power and low-data rate application of electric grid which do not require very high reliability [16].

III. PRELIMINARIES

In this paper, the assumptions that we have made are:

- Each sensor is synchronized with time.
- Specific ID has been allotted to each sensor.
- The coordinator nodes collect data from the sensor nodes.

- A common sink node receives data from the coordinator node.
- All the sensors nodes are statically defined in nature and have the same transmission range.
- Every node except the sink node (FFD) and the coordinator is RFD.

IV. PROPOSED PROTOCOLS

Many researches have been done to analyze the scenario of the disasters virtually so that actions could be taken to deal with such disasters. Loss of life can be avoided by employing the system to the industries, processing the sensed data and providing the necessary warnings. Much analysis has done on wireless sensor network with QualNet 6.1 on ZigBee which is based on IEEE 802.15.4 standards. In this paper, we have proposed the virtual analysis of gas leakage in an industry using QualNet where the sensors are placed in a grid form and analyze the results of throughput, average end to end delay, jitter, network lifetime according to the number of nodes as the number of nodes increases there will be changes in the results. The sensors detect the gas leaking from the instruments that are fitted in the industry. The protocols that are used are the low rate wireless personal are network (LRWPAN), low rate wireless personal area network drift (LRWPAND), low rate wireless personal area network drift and multi-channel (LRWPANDMC). Generic energy model has been used so that we can change the parameters as per our needs. We have considered 38 bytes as the packet size as this will provide optimal results.

Table- I: Simulation Parameters

Parameter	Value(s)
Total number of nodes	*50, 100, 300*
Number of PAN coordinator(s)	*1, 2*
Communication Protocols	*IEEE 802.15.4*
Channel frequency (GHz)	*2.425, 2.450, 2.475, 2.480*
Packet size (bytes)	*38*
Packet interval (secs)	*1*
Simulation Times (secs)	*300*
Battery (mAh)	*300*
Transmission range (m)	*10*
RFD to PAN connectivity	*ZigBee, 2.4 GHz*
PAN to RFD connectivity	*ZigBee, 2.4 GHz*
Terrain Area (m^2)	*100 × 50, 100 × 100, 500 × 500*
Energy Model	*Generic*
Transmit circuitry Power consumption	*24.75 mW*
Receive circuitry power consumption	*13.5 mW*
Sleep circuitry power consumption	*0.0051 mW*
Idle circuitry power consumption	*13.5 mW*
Battery model	*Linear*
Application	*Traffic Generator*

A. Low Rate-Wireless Personal Area Network

In LRWPAN, which is the IEEE 802.15.4 in this we set the range between each sensor as 10m, let us assume that practical range is up to 25m. Only one PAN coordinator would be there which is the fully function device, that would receive the data from the other coordinators through the constant bit rate (CBR).

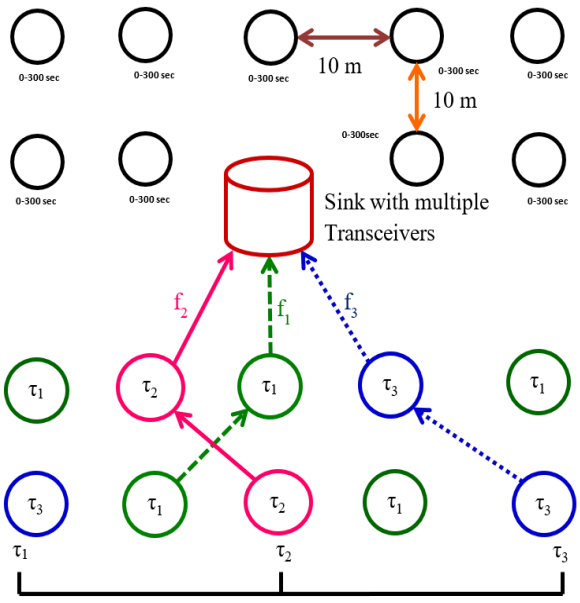

Fig. 1. Simulation architecture of LRWPAN protocol.

Each node except the coordinators and PAN coordinator will be active for 300 secs. If the numbers of nodes are 300 then the number of applications (constant bit rate) will be 300/3. The disadvantage of this protocol is the battery capacity decreases as all the nodes are active for the full-time; this affects the network lifetime and the performance.

B. Low Rate-Wireless Personal Area Network with Drift

The design of LRWPAN-D protocol is presented and implemented in such a way that fully function device (FFD) must always be on and reduced function devices can have different duration of ON and OFF. In this way, the energy is saved to increase the lifetime of the network. For saving the costs of working, it becomes censorious for a network operator to reduce the energy consumption of a communication system. Even though the capacity of batteries for wireless terminals keeps increasing, the increase rate is not fast enough to satisfy users' expectations. Therefore, an energy efficient scheme to save the energy of handheld devices is needed to enlarge their lifetime. The adjacent nodes are set with different activation time so that no collision occurs between the packets when these are being sent to the sink node. The number of contending nodes are decreased which reduces the collision and increases the throughput. When the sensors which are active at the same time start sending packets, the packets may collide and the information may get lost.

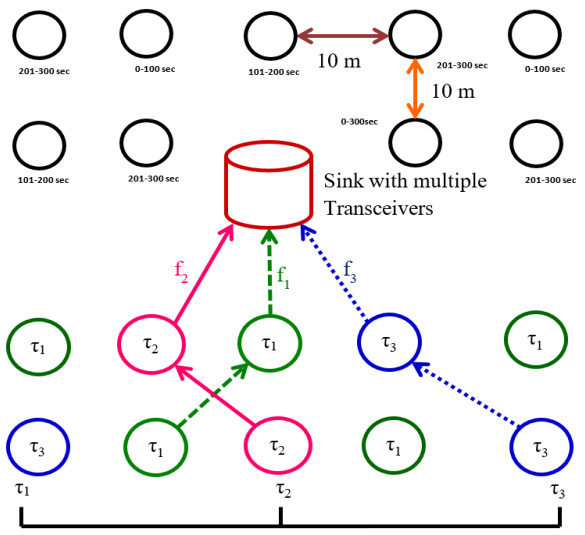

Fig. 2. Simulation architecture of LRWPAND and LRWPANDMC protocols.

C. Low Rate-Wireless Personal Area Network with Drift and Multiple Channels

To prevent the collision and congestion among the packets, the nodes which are active simultaneously must transmit data at different frequencies of 2.425 GHz, 2.450 GHz, 2.475 GHz and 2.480 GHz. It means the nodes which are active for 0-100 sec must send packets at 2.450 GHz, 2.450 GHz, 2.475 GHz and 2.480 GHz and likewise till nodes which are active for 300 sec. The reduced function devices (RFDs) are equipped with only one transceiver operating at only one frequency out of these four frequencies. This reduces the bottleneck problem at the sink node. So, to receive multiple signals of different frequencies the PAN coordinator should have four different transceivers operating at frequencies of 2.425 GHz, 2.450 GHz, 2.475 GHz and 2.480 GHz.

V. RESULTS AND DISCUSSION

A. Effect of Protocols on Throughput

The comparison of LRWPAN, LRWPAND, LRWPANDMC for throughput is shown in fig. The implementation of multichannel has been proved to be more effective than other protocols to improve the throughput.

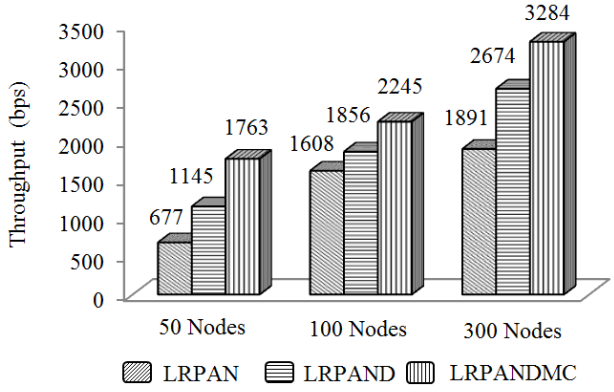

Fig. 3. Influence on throughput.

B. Effect of Protocols on Average End to End Delay

As the number of contending nodes has reduced, the formation of bottlenecks is also reduced as the overloading of a particular sensor has been eliminated. The main causes of end to end delay is the duplication of packets and when all the nodes send the packets at the same time. The increment of waiting time, service time and congestion are the major cause of the increasing delay.

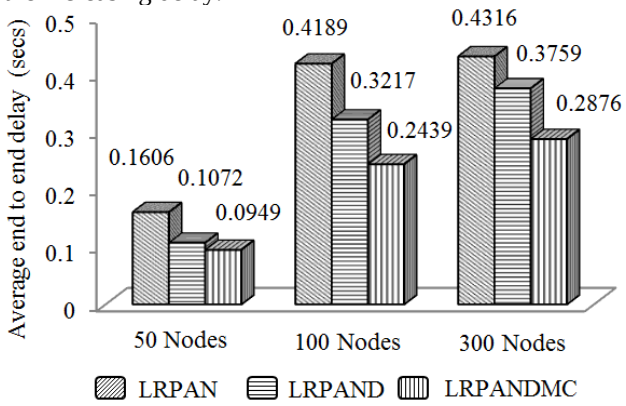

Fig. 4. Influence on Average End to End Delay.

C. Effect of Protocols on Jitter

The transmission and reception of censorious information time to time is of utmost importance to react proactively to prevent any accident. To preserve the consequences of the information the jitter must be less. LRWPAND-MC stand out to be the admirable protocol among all as it reduced and maintained the values.

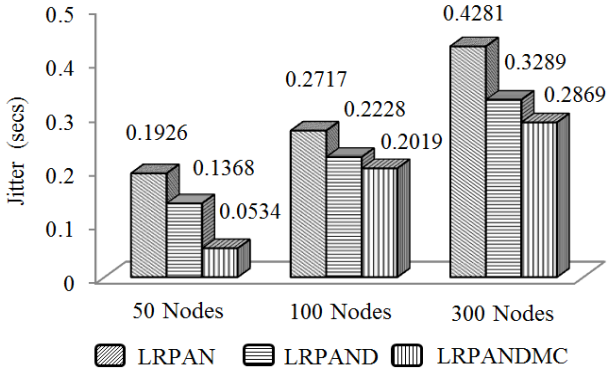

Fig. 5. Influence on Jitter.

D. Effect of Protocols on Network Lifetime

The priority of this research is achieved with great success, that is the lifetime of the network as it is very expensive and not possible to change the batteries of the sensors many times specially in remote areas. The accidental or irrelevant transmission, hearing and the reception of redundant data packets has significantly reduced the energy consumption. These results showed that LRWPAND-MC stood best among LRWPAND and LRWPAN protocols.

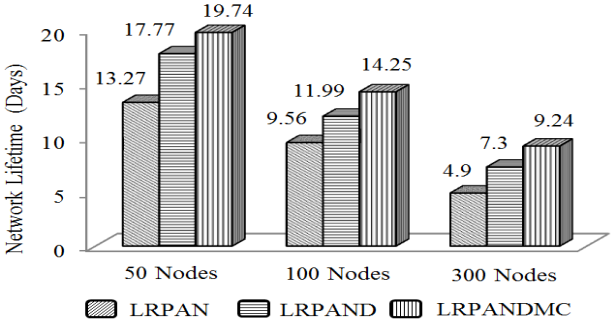

Fig. 6. Influence on Network Lifetime.

VI. CONCLUSION

In this paper, three types protocols have been implemented separately on the simulation platform. Performance of various protocols (LRPAN, LRPAND and LRPANDMC) has been observed by changing the terrain area which is 100×50 m^2, 100×100 m^2, 500×500 m^2 for different numbers for nodes which are 50, 100, 300. The simulation results show that the LRPANDMC for all terrain areas achieved optimized performance. The objective of this paper to find out the most effective and efficient protocol is successfully achieved. The protocols such as LRPAN and LRPAND provide optimal results for a smaller number of nodes but it will create collision among packets received by the sink nodes but the LRPANDMC will give accurate information to the sink node in different terrain areas. The network engaged with LRPANDMC will give accurate results and early warnings and can avoid huge damage to property and human life. The QualNet 6.1 has provided accurate results which is very helpful for deploying sensors in real-time scenario. The conclusion drawn is that LRPANDMC is the most efficient and appropriate protocols for 500×500 m^2 terrain area deployed with 300 nodes. Presently, WSN is considered and developed as an effective and efficient technology for the realization of Internet of Things (IoT).

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