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Inter-communication between Swarm-Bots

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ABSTRACT

As physical and digital worlds are merging it is changing the dynamics of the industries in India. The German Academy of Science and Technology coined the term fourth industrial revolution (Industry 4.0) changing the industrial process dramatically with automation and robotic technology at rising. With the advancement of robotics technology, the complexities are also increasing which has led to the development of one of the strong arms of the technologies of the industrial revolution- Swarm- robotics. Swarm intelligence take its inspiration from social animals and display the concept of collective behavior. With simple hardware architecture, high feasibility, cost efficiency, robustness; it comes out as a very user-friendly technology which is fit for the industrial applications where depending on a single robot for the accomplishment of a task is not possible. The only challenge this multi-robot technology faces is to establish an efficient communication system between them to ensure proper coordination, communication, and routing. ZigBee technology was thus proposed as a solution as it fits perfectly with the features of swarm robotics and improves the efficiency of the mobile robots.

Keywords— *Swarm-Bots, Zigbee technology, Intercommunication*

1. INTRODUCTION

Swarm robotics originated with the idea for collective robotics that takes inspiration from biology that is, self-organized behaviors of social animals like ants, termites, wasps, bees and other social insects. Swarm robotics has been defined as a novel approach to the coordination of large numbers of robots and as the study of how large numbers of relatively simple physically embodied agents can be designed such that a desired collective behavior emerges from the local interactions among agents and between the agents and the environment. [1]

Sometimes a stand-alone robot fails to complete a certain complex task. This failure brought in the concept of swarm robotics. Swarm robotics deal with collective-decision making to accomplish a task. Such robots are autonomous and robust in nature. They do not have centralized control.

This collective behavior in swarm robotics technology requires an efficient communication system between them for proper coordination and mutual consultation. Due to a large number of mobile robots involved in the accomplishment of a single task, the communication module becomes complex and a challenging task. Proper sharing of information and instruction between each robot of the system is very important for the successful accomplishment of the task. Hence selection of proper communication technology for swarm robots in accordance with the application, cost, and environment is very important. Generally, short-range-wireless-communication techniques are best suited and match the characteristics of swarm robotics.

In this paper, we are going to study the basic construction of each robot, comparison of various short-range communication methods in the market, advantages of using Zigbee technology for swarm robotics, specifications and the design of communication module for robots.

2. LITERATURE SURVEY

A lot of time and resources can be saved and it can be redirected to develop more innovative ideas instead of repeating the same or existing searches.

2.1 Hardware structure of the robot

Swarm robotics has the concept of multiple robots collectively working together. Hence a simpler construction of each mobile robot should be taken into consideration. Figure 1 shows a generalized structure swarm robot. [2]

Micro-controller or CPU of the robot is selected according to the complexity of the system as well as the application. The microcontroller drives the drivers, which manage the movement of actuators according to the instruction received by the CPU. The actuators can be motors attached to grippers, wheels depending upon the application.

The power supply is used to drive the system that is, the robot as a whole. The robots are expected to have long battery life and hence each component selected should have low power consumption.

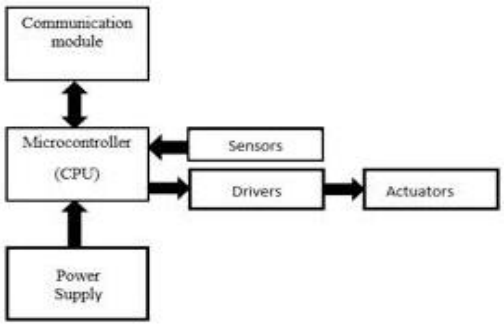

Fig. 1: Hardware Structure of Individual Robot

Table 1: As inferred from [8] comparison between various wireless communication standards

Name of Technology	International Standard	Data Rate	Transmission Range
Infrared	-	9.6 kbps to 16 Mbps	1m (Long range up to 2.4 km)
Bluetooth	IEEE 802.15.1	780 kbps to 2.1 Mbps	10m (Long range up to 1 km)
Wi-Fi	IEEE802.11b/g	11 Mbps to 54 Mbps	20 m - 46 m (Outdoor up to 92 m)
ZigBee	IEEE 802.15.4	20 kbps to 250 kbps	10 m - 20 m

The communication module is a very important block of the robot, which ensures the fulfilment of the main characteristics of swarm robotics of coordinated and collective behavior of robots.

2.2 Different Communication Modules

Between the robots of the swarm, selection of the correct communication module is necessary. The rapid development of communication technologies has made wireless communication a trustworthy and efficient mode of the same. Wireless Local Area Network (WLAN) is based on IEEE 802.11 standards that use has some advantageous, such as high capacity, wide coverage and able to broadcast directly.

When the range of communication is from few centimeters to a few meters a technology known as Wireless Personal Area Network (WPAN) is used. The prominent short-range wireless communication, are infrared technology, Bluetooth technology, IEEE 802.11b and ZigBee technology. Comparison between various Wireless communication Standards are shown in Table [1] [2]

As inferred from the comparison each standard has its upper hand in particular applications. Infrared is strict with a line of sight, while Bluetooth typical effective range is short and has a lower data rate. IEEE 802.11b has a higher data rate and effective communication range but high power consumption is an issue. ZigBee has a lower data rate but a considerable battery life and works very well with applications with a large number of nodes. Thus ZigBee is a most suited communication module for swarm robotics.

3. ZIGBEE TECHNOLOGY

Robot in a mesh network act as a sensor node which performs 3 functions: a collection of information through sensors, computation of the collected data according to the instructions or commands feed in microprocessor and communication through communication module that is ZigBee. It consists of transceivers for transmitting and receiving data between the nodes.

ZigBee, a standard developed by ZigBee Alliance defines a communication protocol for wireless networking. The devices following ZigBee protocol work in 868 MHz (Europe), 915 MHz (America), and 2.4 GHz (worldwide) frequency bands with a maximum data rate of 250 kilobytes per second. As these frequency or wave bands are different from other wireless networks, mutual interferences will not occur. The three main features of ZigBee protocol is long battery life, low data rate and low cost which makes it the most preferred communication protocol for battery operated applications. [3]

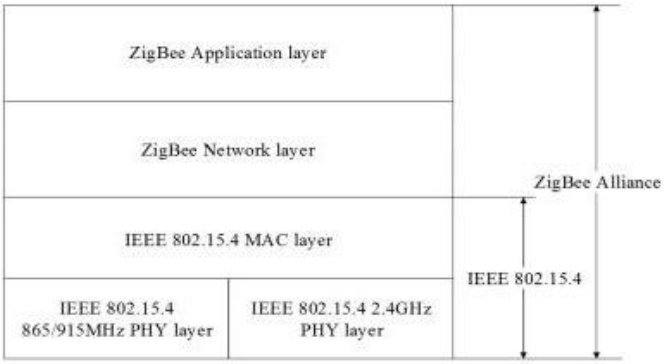

Fig. 2: ZigBee architecture

This project uses XBee S2C as communication module. Series 2C modules give you a chance to work on complex networks. S2C is also compatible with older series version S2. The Nodes in ZigBee can be of three types depending on the freedom of communicating routes available to them. [6]

(a) Coordinator: The root of any network tree is formed by a coordinator. Coordinators are also responsible for initialization and selection of parameters of the network as well as establishing connectivity with other network topologies.

(b) Router: Router or intermediate nodes convey information from one device to another. Either connecting to an established network or accepting the request of other devices to connect to its network is done by the router. Hence extending an existing network.

(c) End Devices: Mobile robots of the swarm can be termed as end devices which carry out tasks such as collecting data through different sensing devices and switches. Even though they cannot relay information from one node to another, they can communicate efficiently with the coordinating node.[5]

4. DESIGN AND IMPLEMENTATION

Designing a prototype of swarm robotics project for a real-time application is a challenging task. In this project, the number of mobile robots to be considered in a swarm is eight. Each robot is in accordance with a swarm robot, robust, simple design and long battery life.

4.1 Block diagram of Individual Bot

Construction of each robot of the swarm has to fulfil certain constraints such as low cost, simpler design, proper power supply, necessary sensory devices and micro-controller.

Every bot consists of Arduino Uno as a microcontroller, various motors as actuating devices and Ultrasonic Sensor HC-SR04 as a physical sensor. Eight such bots form the Hardware system or the swarm of the system.

Second Most important Module is the communication module, which consists of wifi module, Gateway and ZigBee Module to enable communication between the User Interface and Swarm of bots.

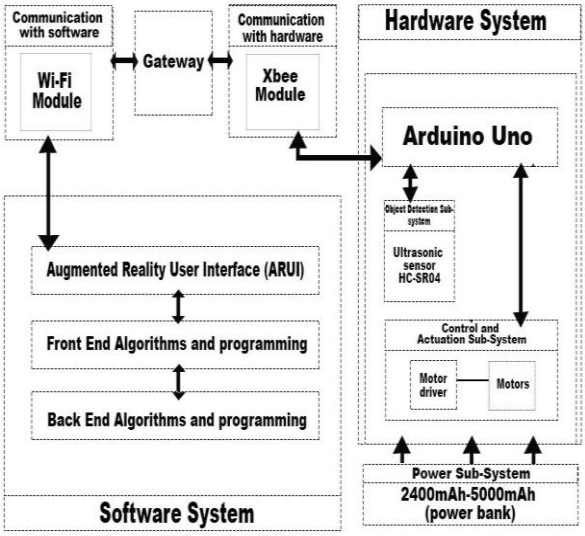

Fig. 3: Schematic diagram of the system

4.2 Design of Communication Module

For any Xbee to communicate with other Xbee it is necessary to configure it. After configuration of each Xbee, the protocol has been designed specifically to the project, and thus the network has been formed through broadcasting. [4]

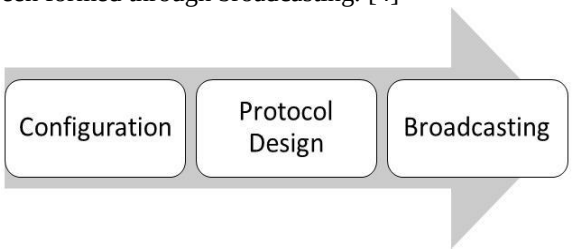

Fig. 4: Communication Module Design Flow

4.2.1 Configuration of XBee device: One of the prime features of swarm robotics is its decentralized control. In order to satisfy this condition, all eight robots (sensor nodes) have been configured as routers and a separate Xbee S2C as coordinator.

Sr No.	Coordinator	Router
1	+++	+++
2	ATID= XXXX	ATID=XXXX
3	ATSC=7FFF	ATJV=1
4	ATSD=3	ATSC=7FFF
5	ATZS=0	ATSD=3
6	ATCE=1	ATZS=0
7	ATNJ=FF	ATCE=0
8	ATDH=0	ATNJ=FF
9	ATDL=FFFF	ATDH=0
10	ATAP=0	ATDL=0
11	ATWR	ATAP=0
12		ATWR

Fig. 5: AT Commands

The XBee device works in two different modes: Application Program Interface (API) and Application Transparent (AT). In AT mode the data is not formed in packets before transmission and sends directly to the destination address. While in API mode the data is formed in frames before transmission and thus receives acknowledgement signal from the remote module once the frame is received.

To simplify the process of designing communication, a series of AT commands as shown in figure 5 have been used to set Xbee devices as coordinator and router. An open software serial monitor TeraTerm has been used to execute the same.

4.2.2 Protocol Design: Protocol designing is an important part of the communication module. It helps in organized transmission of data from one node to another. Specific to the project the data to be transmitted between the coordinator and routers are the position coordinates of each robot.

##	Robot no.	$$	xx	;;	yy	**
Start of the frame	Helps router to recognize its specific data	Separating character	X-coordinate of the robot	Coordinates separating character	Y-coordinate of the robot	End of the frame

Fig. 6: Frame design

Figure 6 portrays the defined frame to be broadcasted. The coordinator is responsible for the formation of the frames.

4.2.3 Broadcasting: After protocol designing the next step is the formation of the network between the devices. Each router (node) is assigned a specific number known as 'Robot number'. The coordinator is responsible for the formation of frames which is broadcasted to all routers at the same time. The router identifies its particular data based on the 'Robot number' in the frame. In this way, a network is formed between coordinator and routers.

5. RESULT

This project involves the accomplishment of the task using a swarm of eight mobile robots. Exchange of frame between coordinator and routers enables the robots to execute the given task. Among the frames sent by the coordinator initially, the router first identifies its particular frame and then retrieves the data to process and perform the task according to the pre-defined algorithm.

6. CONCLUSION

In this paper, we have seen that with increasing development in robotics technology, the complexities and constraints based on applications are also increasing.

With the increase of infusion of robotics in industries as well as consumer lives so rapidly, swarm intelligence would be in high demand due to its feasibility, cost efficiency and simple approach. Swarm robotics brings in the picture the collective behaviour phenomena for efficient completion of a task. But as the number of robots increase, to establish perfect coordination or communication between them plays a very important role. After reviewing various short-range communication technologies, Zigbee was recognized as a perfect communication standard to be used in swarm robotics; due to its low cost, long battery life and efficient short-range communication. This paper also discusses hardware requirements necessary for establishing intercommunication between mobile robots, the designing of the communication module specific to swarm robotics and the flow of transmission of information between XBee devices.

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