COMPARATIVE ANALYSIS OF WIRELESS TECHNOLOGIES FOR INTERNET-OF-THINGS BASED SMART FARM

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ABSTRACT— *Internet-of-Things (IoT) is an emerging technology that is connecting the physical things to the internet to achieve smart capabilities in various fields. In this paper an overview of different wireless technologies is presented to provide connectivity to the physical things, particularly for a poultry farm. In a farm, connecting several sensors and automate various tasks and some data analytics, can be used to improve farming. It can also be used to easily monitor the environment of the poultry farm, thus providing better monitoring and control. The analysis of different technologies is carried out and the ZigBee and LTE technologies are found to be the most feasible and economical solutions for a smart poultry farm.*

Keywords— Internet of Things, smart poultry farm, wireless technologies, smart enviroment, ZigBee, LTE, Bluetooth, IoT

INTRODUCTION

In most of the countries, the demand of poultry meat is increasing progressively because of high protein, low energy and low cholesterol meat. The high production of chicken depends on the environment, breeding process and the active operations [1]. To monitor and control the farm actively, in most cases sufficient manpower is required, however in turn it increases the production cost significantly. So it requires a mechanism that may manage the poultry farm easily for better improvement in the production with lower cost.

Usually, the poultry farms are located in suburbs, away from populated areas, as shown in Figure 1. There can be more than one poultry farm nearby, and it requires a lot of manpower (labor) to manage each poultry farm. The advancement that has been made in the technologies now make it possible for remote monitoring and controlling system and thus reduces the manpower cost and enhances the production [2]. By utilizing the internet-of-thigns (IoT) system, this goal can be achieved easily. IoT can be defined as many physical objects (having capability of sensing something from environment) connected to a WAN (Wide

Figure 1: An aerial view of typical poultry farm location (Eastern region of Nigeria) [4]

Area Network) network to collect, share and convey information for some analysis. With the help of these small network connected sensors or objects we can easily control a certain system [1]. There is a great extent of using IoT like smart hospital, smart home and smart traffic. Smart poultry farm system can be a good implementation of IoT system. IoT can help the poultry farm owners to enhance production while lowers the cost substantially. The size of poultry farm is generally 60 x 120 meters [3]. Different type of controller and monitoring devices are used to maintain the temperature, humidity, feeding and watering inside poultry farm[2], as shown in Figure 2, that may be controlled remotely.

In some developing countries, there are certain issues, such as lack of water, hard weather conditions, lack of infrastructure and transport facilities. For such countries an IoT based smart poultry farming may help to resolve these issues up to some extent. As discussed earlier, there can be environmental monitoring and controlling system which can be controlled remotely. These monitoring and controlling system are often based on wireless network [5]. Wireless communication is steadily grows in recent years and it can be easily implemented in a places, that are located in remote areas with hard weather conditions and without complete communication infrastructure. For these reasons, wireless network has advantage over wired network, and seen as a best candidate to avoid the cable layouts and its management [3]. In a wireless communication, the Wireless sensor network (WSN) is most suitable for such type of environments.

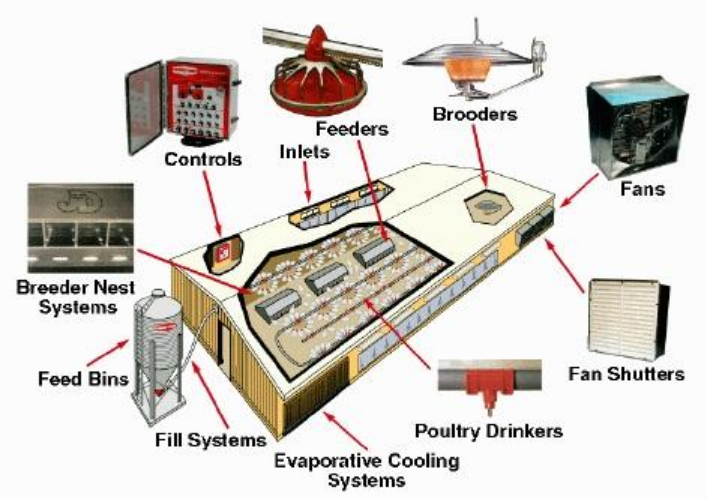

Figure 2 : Basic equipment that used in a poultry farm

It provides connectivity to different sensors while inter-connected with internet using a wide area network (WAN). The WSN is consisting of small sensor nodes, coordinator and internet gateway (WAN access)[6]. Sensor node has low processing and power capabilities than a coordinator. A coordinator is a powerful device which has more processing capabilities and a good battery life. An internet gateway can

be a cellular network or any other internet access point. An overview of wireless connectivity of typical poultry farm is depicted in Figure 3.

In this article, comparative analysis of different technologies is performed and on the basis of that analysis a best solution for wireless connectivity of a poultry farm, is outlined.

The next section provides the overview of different existing communication protocol and their vulnerability in term of power consumption and range, and the last section presents comparative analysis and proposed an implementation of best suitable wireless network for poultry farm .

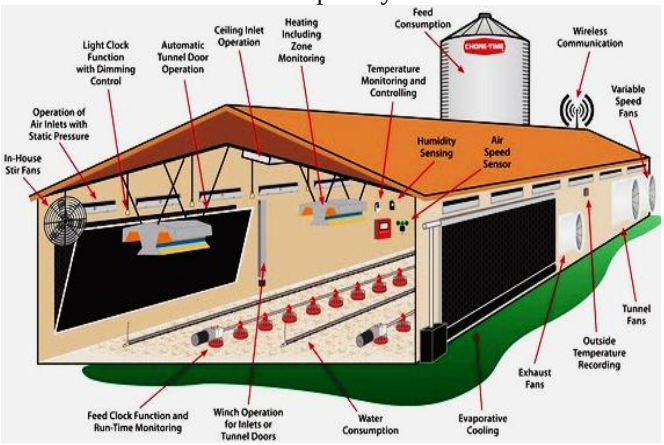

Figure 3 : An overview of accessories and wireless connectivity of smart farm [4]

WIRELESS TECHONOLGIES BACKGROUND

Wireless sensor network are generally considered as a network with limited resources, like battery power and processing capabilities. There are many technologies that are being used for wireless sensor network[7]. The Wireless protocols in IEEE 802.15 standard, includes Bluetooth, UWB and ZigBee etc. and belongs to a category that has low power and short range. Another wireless protocol IEEE 802.11ah is also discussed under low power short range scenario, but it is an extension of existing WiFi 802.11 a/b/g/n standards. It is noticeable that these IEEE standards defines only physical and MAC layers. All the layers above them are normally developed by the alliances of company. The basic goal behind these alliances is to define the specification of remaining layers to commercialize the standards. Here is the some review of these techniques with comparative analysis, while considering poultry farms as an application.

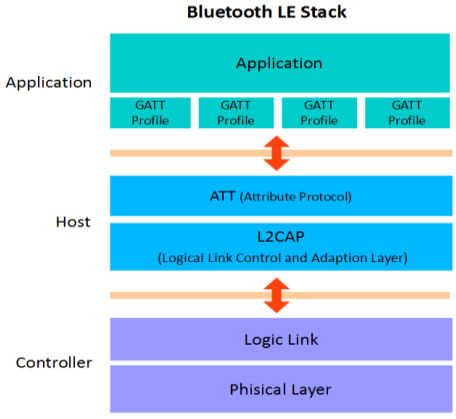

Figure 4 : Bluetooth Layered Stack

1. BLUETOOTH TECHNOLOGY

The IEEE 802.15.1 standard, i.e. Bluetooth is a communication technology operates in short range with very low power consumption[8]. The main function of Bluetooth was to replace the wired connectivity of the human intractable devices such as headphone, keyboard and mouse etc. [9]. There are multiple operating modes of devices includes Active and Parked etc. Each has different characteristics in term of power consumption and data transfer capability. BLE (Bluetooth 4.0) is the upgrade version of IEEE 802.15.1 standard Bluetooth as shown in figure 4. Low cost is one of the best feature which dominates it from other contemporary technologies. Bluetooth compliance devices can be connected in two network topologies. One is Pico-net and other is Scatter-net. Pico-net has same characteristics as Infrastructure mode IEEE 802.11x. There can be maximum 8 devices in Pico-net including exactly one master and reaming are slave. Communication channel between master and slave devices are based on frequency hopping. Master device in Pico-net controls and synchronize communication by providing a common clock to all devices. All communication is routed via Master device and no direct communication among the devises is possible. Scatter-net is an example of Mesh network formed by different Pico-net with common slaves devices overlapped in both time and space. Scatter net basically extends the Bluetooth network [10, 11]. BLE is now in commonly used and are mostly embedded in cell phones. It can be a part of an IoT system like connectivity of healthcare devices and smart home devices intractable from cell phone.

2. ULTRA WIDEBAND TECHNOLOGY

The IEEE 802.15.3 UWB (Ultra Wideband) is an advance communication technology which provide high data rate. It has low power consumption with short range in contrast with other technologies[12]. It is considered very well for indoor use because it has capability of penetrating through obstacles, doors, walls and metal objects. It can provide data rate up to 480 Mbps which make it suitable for high data rate applications. It make use of very wide band typically in Mega Hertz to transmit data. Data is transmitted at all frequencies in the band simultaneously in the form of pulses. These pulses are of very short duration and are send in very time precisely manner. To accurately send and receive pulses, high level of coordination is required between sender and receiver. The restriction of high level synchronization can make it inefficient in many scenarios especially for small resource constraint devices having less synchronization capabilities[13]. However medium size devices which normally contain good processing capabilities can utilizes UWB efficiently due to adequate synchronization capabilities. High bandwidth nature of UWB can also make it infeasible in a scenario where frequencies are scar resource. Layered stack of UWB is as shown in Figure 5.

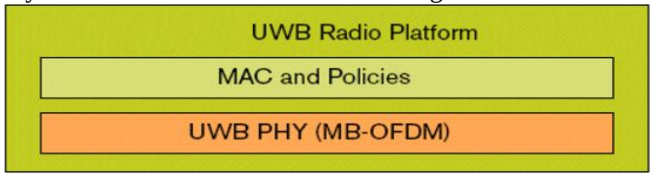

Figure 5 : Ultra-Wideband Layered Stack

3. ZIGBEE TECHNOLOGY

The IEEE 802.15.4 ZigBee is a variation of IEEE 802.15.4 LoWPAN WPAN standard which is developed by ZigBee alliance. This protocol is reside on the top IEEE 802.15.4 as shown in Figure 6.

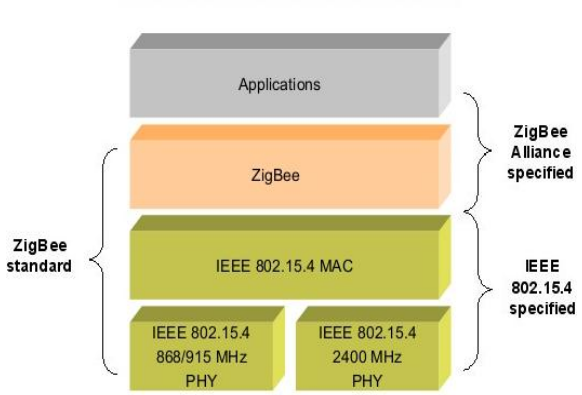

Figure 6 : ZigBee Layered Stack

This protocol was specially designed for low data rate, low power consumption and long transmission range [14, 15]. It uses carrier sense multiple access with collision avoidance (CSMA-CA) scheme. In CSMA-CA multiple users or nodes can access the same channel at different time without any interference. It has two topologies, one is star and other is P2P (peer to peer). In star communication of all nodes are pass through coordinator node. In P2P any device can communicate to other node in network[16]. The combination of these two topologies can forms it into mesh topology as shown in figure 7. By using these topologies ZigBee form to a strong network. Any node can communicate to coordinator if it is not directly in range, it can communicate through other node, moreover if a relaying node is dead transmitting node can use alternate path which is shortest. This feature enhance its reliability in the network. It is now in common use due to its low power consumption and somehow maintenance free. The ongoing projects of ZigBee alliance are smart energy, and home, building, and industrial automation[16].

4. WIFI TECHNOLOGY

The IEEE 802.11a/b/g/ac/ah are the sub-part of IEEE 802.11 WLAN standard, which is especially designed for indoor communication with high data rate. Some of these are licensed and standardized on the frequency band 2-5 GHz. These are more robust but limited to shot range about 100 meters. To enhance the range and other functionality some nonstandard modified version are also defined.

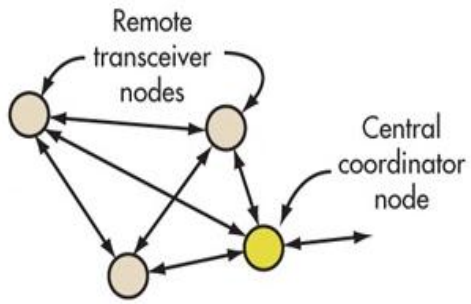

Figure 7: ZigBee network Nodes

IEEE 802.11ah is one of nonstandard standard Wifi WLAN which operates in 900 MHz[17]. IEEE 802.11ah named HaLow has different advantages over the standardized WLAN such as long range with low power. The use of low frequency is not only beneficial in term of extending range but also having low power consumption. It has data rate is slighter higher than WPAN devices. Another characteristic of 802.11ah HaLow is to transmit a minimum 150Kbps data.It can be used to connect many of sensors to server or conventional network but where little bit lower data rate is required because it has megabit per second transfer rate rather than as standard WLAN. It enables the low power sensors to be operated without need of a power amplifier. Due to these features it is supposed to be best for IoT system. It make use of low power MAC protocol which help the sensor in lowering their power consumption as shown in Figure 8.

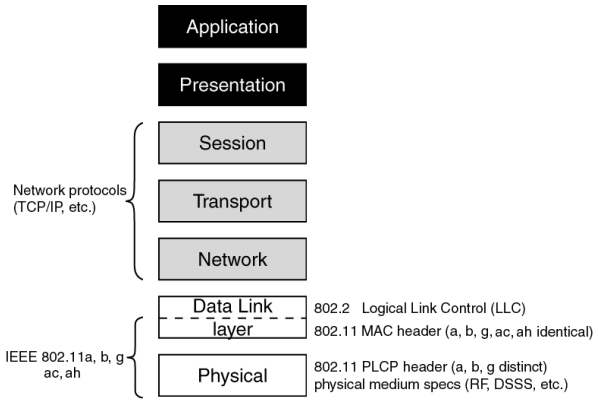

Figure 8 : WiFi Layered Stack

5. WIMAX TECHNOLOGY

The WiMAX (World Wide Interoperability for Microwave Access) is an advance communication technology based on IEEE 802.16 standard. It is basically a wireless broadband service alternative to DSL[18]. It provides point to multi point connectivity. IEEE 802.16 standard can transfer data at rate of 75 Mbps up to 3 mile range. It works in licensed LOS (Line Of Sight) 10-60 Ghz and unlicensed NLOS (Non Line Of Sight) 2-11 Ghz band. Licensed LOS band is used for MAN (Metropolitan Area network) whereas unlicensed NLOS band provide connectivity to end users which have the range between 3-5 miles[19] as shown in figure 9. It supports different radio access network topologies which enables it to compatible with Wi-fi, 3GPP and existing IP networks. It has two MAC and PHY layer specification which have different operating bands in different countries. In Pakistan WiMAX service providers are Wateen, Qubee and Witrib which uses around 3 GHz frequency band. Future use of WiMAX will not only for home/fixed users but also provisioning of connectivity to mobile users. One of good feature of WiMAX is it enables the users with suitable data rate according to signal strength due to distance like close enough or far from transmitting tower. It provide different QoS which can fulfill the needs of user such as real time data and multimedia time services.

	802.16	802.16a	802.16e
Spectrum	10 – 66 GHz	2 – 11 GHz	<6 GHz
Configuration	Line of Sight	Non- Line of Sight	Non- Line of Sight
Bit Rate	32 to 134 Mbps (28 MHz Channel)	≤ 70 or 100 Mbps (20 MHz Channel)	Up to 15 Mbps
Modulation	QPSK, 16-QAM, 64-QAM	256 Sub-Carrier OFDM using QPSK, 16-QAM, 64-QAM, 256-QAM	Same as 802.16a
Mobility	Fixed	Fixed	≤75 MPH
Channel Bandwidth	20, 25, 28 MHz	Selectable 1.25 to 20 MHz	5 MHz (Planned)
Typical Cell Radius	1-3 miles	3-5 miles	1-3 miles
Completed	Dec, 2001	Jan, 2003	2nd Half of 2005

Figure 9 : WiMax Varitants

6. GSM TECHNOLOGY

The GSM stands for Global System for Mobile communication. It was commercially deployed in 1992 which gives analog calling facility. Later on after advancement named 2G (2nd generation) enhanced its features which include digital call, SMS (Short Messaging Service) and CLI etc. It operates in 850, 900 and 1800 MHz frequency band. In GSM architecture regions are divided into cells, each cells is provided with coverage of 2 to 3 Km using BTS (Base Transceiver Substation) which is further connected to base network.

2G	2.5G		3G		4G	
Name	Name	Download	Name	Download	Name	Download
TDMA	GPRS	115 Kbit/s	*WCDMA (UMTS)*	*384 Kbp/s*	*LTE*	*100 Mbp/s*
	EDGE	236 Kbp/s	*HSPA (UMTS)*	*14 Mbit/s*	WIMAX	50 Mbp/s
					HSPA+	56 Mbit/s
CDMA2000			EVDO (CDMA2000)	3.1 Mbit/s		

Figure 10 : Data rates of Cellular Technologies

As shown in Figure 10, 2G network introduce concept of GPRS which enabled at max user to get connected with internet at max speed of 115 kbps. GPRS was with very low data rate where high data rate application was not be supported. 3G network technology (EDGE) was introduced to support high data rate. Although EDGE was already introduced but it was limited to 384 Kbps. 3G makes use of a technique WCDMA which efficiently utilizes the both TDMA & FDMA which enhance the data rate up to 2Mbps[19, 20]. It has also a feature of adaptation modulation which enables the users at different distances from BTS can achieve different data same as WiMAX. To enhance more speed and making the air interface more efficient 4G LTE was introduced and was commercialized in 2008 which is now practically in use. After enhancement in 3G to 4G network data rate was increased to 14.4 mbps for downlink (with the help of HSDPA) and 5.74 for uplink (with the help of HSUPA)[21]. The invent of 4G is not only to get 100 Mbps but also high QoS, low complexity, enhance range and integration in with existing IP network. 4G LTE is introduced in Pakistan in 2014 and its average speed is 4 Mbps.

COMPARATIVE ANALYSIS OF WIRELESS TECHNOLOGIES

Vocational In above section, an overview of wireless protocol are discussed in different aspects, for internal communication of farm house different low power wireless protocols was reviewd and same as for external connectivity WiMax and LTE was discussed keeping in view an IoT system. In this section a comparative analysis is given and proposed a best fit wireless protocol for poultry farm. For unmanned type poultry farm there is a need of minimum power consumption with long lasting battery life because power consumption with respect to battery are the most critical problems of small sensing wireless devices. Even in some cases complete replacement of device is less cost effective than replacing the battery of the devices.

No doubt WLAN standards are the best for wireless communication especially IEEE 802.11ah with long range but in comparison with ZigBee and BLE, have more power consumption. BLE (Bluetooth 4.0) and ZigBee are best choice for those application where low data is required with limited battery power, this minimum power consumption leads them to long lifetime. Whereas UWB and WiFi is best in term of high data rate but power consumption is slight higher than BLE and ZigBee as shown in Figure 11.

Wireless Networking Technologies				
	ZigBee	**Bluetooth**	**UWB**	**Wi-Fi**
Standard	IEEE 802.15.4	IEEE 802.15.1	IEEE 802.15.3a (to be ratified)	IEE 802.11a, b, g (n to be ratified)
Industry organizations	ZigBee Alliance	Bluetooth SIG	UWB Forum and WiMedia Alliance	Wi-Fi Alliance
Topology	Mesh, star, tree	Star	Star	Star
RF frequency	868/915 MHz, 2.4 GHz	2.4 GHz	3.1 to 10.6 GHz (U.S.)	1 GHz, 2.4 GHz, 5.8 GHz
Data rate	250 kbits/s	723 kbits/s	110 Mbits/s to 1.6 Gbits/s	11 to 105 Mbits/s
Range	10 to 300 m	10 m	4 to 20 m	10 to 100 m
Power	Very low	Low	Low	Low/High
Battery operation (life)	Alkaline (months to years)	Rechargeable (days to weeks)	Rechargeable (hours to days)	Rechargeable (hours)
Nodes	65,000	8	128	32

Figure 11: Compasion of most popular Wireless Technologies

Moreover in network point of view Bluetooth and UWB have limited number of nodes in their network whereas ZigBee can be a 65000 nodes network and same as WiFI may have 2007 nodes network.

In poultry farm prospective, here required a solution which leads in term of range and low power consumption. In this paper proposed solution is ZigBee. As shown in figure 11 ZigBee has long range with respect to others moreover its power consumption is also low. No doubt BLE is also very low power but its range is limited. One more thing which leads the ZigBee protocol with other is it can work under large network [22, 23].

Radio interface	Peak downlink rate	Estimated realistic spectrum efficiency	Average throughput		
			5MHz transceiver	10MHz transceiver (where applicable)	20MHz transceiver (where applicable)
W-CDMA	Up to 384kbps	0.14bps/Hz	0.7Mbps		
HSPA	Up to 14.4Mbps	0.4bps/Hz	2Mbps		
HSPA+	Up to 42Mbps	0.9bps/Hz	4.5Mbps	9Mbps	
LTE	Up to 45Mbps (5MHz) Up to 326Mbps (20MHz)	1.4bps/Hz (10MHz)	6Mbps	14Mbps	30Mbps
LTE-Advanced	Up to 1Gbps downlink (using up to 50MHz)	1.8bps/Hz (20MHz)	8Mbps	17Mbps	36Mbps

Figure 12: Compasion of Cellular Technologies

As shown in Figure 12 for WAN support, cellular network is the best approach because it has network coverage almost everywhere (urban and rural area), whereas WiMAX are only available in urban area. As discussed earlier almost all poultry farm are located far from population area close to rural area, WiMAX would be infeasible approach moreover WiMAX is still facing with many technical challenges[24]. In cellular network most preferably 4G LTE can be utilized otherwise 3G cellular network can be utilized. One more benefit of using cellar network is SMS service where SMS alert service can also be utilized in poultry farm in case of any abnormality occurs.

CONCLUSION

The paper has presented an overview of wireless technologies that are available for an Internet-of-Things network. It provides comparative analysis and also proposes the most suitable communication technologies for remote monitoring of a poultry farm utilizing an IoT concept. Although there are many other existing technologies that provide low power, long range, low cost and monitoring of a poultry farm, however, ZigBee is found to be most suitable for communication between different sensors. Since remote monitoring of a poultry farm, requires connectivity to a wide-area-network. For this purpose, 4G LTE cellular network is proposed, which is found to be most feasible and cost effective solution than other comparable technologies. Ultimately, it provides an end-to-end connectivity solution to establish an IoT based smart farm.

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