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Recommendations for the Best Communication Technologies for Automated Systems in Urban and Rural Environments

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Abstract – *With the advancement in technology, automated systems are on the rise. These systems make life easier by reducing the amount of menial and trivial tasks that humans had to perform themselves. These systems need a way to communicate to stay in sync or send data to other systems to be more efficient. However, the same type of communication technology cannot be used for all the systems and they vary from point to point depending upon the location where these systems are installed. For example, an automated system installed in an urban location might employ Wireless Fidelity (Wi-Fi) or ZigBee wireless communication protocol and on the other hand, an automated system employed in a rural area can employ Low-power wide-area network (LPWAN) due it its availability, ease of use and its range capabilities. This paper concentrates on why automated systems require communication facilities and what are the ideal communication protocols that the automated systems installed in rural and urban areas.*

I. INTRODUCTION

Automated systems are widely on the rise with the advancement in technology every single day. These systems reduce the number of human interventions required in the task being performed, allowing humans to concentrate on the non-trivial and more important tasks where their attention is required. Most automation systems involve some kind of communication, either with a server for computation or transfer of data to another system to establish efficiency and data transfer as in chatbots. Certain implementations of automated systems that involve sensors utilize the sensor information in a feedback loop, process this information, and send to the actuators the control commands to be executed. Because of the uncertainties in process knowledge and environmental circumstances, such closed-loop feedback control is required [1].

In many automated systems, some subsystems can communicate with each other via communication networks that can be wired or wireless. As Nicholas Kottenstette and Panos J. Antsaklis state in [1], that in many automated systems as in Anti-lock Brake Systems(ABS) or among unmanned aerial vehicles that communicate among themselves to coordinate the flight paths, communication plays a key role in such cases. Automated systems require some sort of communication protocol to remain synchronized or to share any data.

When we consider automated devices that are implemented in different scenarios (Urban and Rural environments), the choice of the communication protocol is very important especially when they have to communicate with a remote subsystem or a server. Now, the choice of communication protocols differs in each of these locations and several factors have to be considered while choosing a network architecture suitable to a particular location. For example, we need to consider the type of communication, as in can we implement a wired communication protocol or do we have to go wireless, we need to consider the range of communication and decide if we need a short-range communication protocol or a long-range communication protocol. Additionally, we also have to consider the availability of the facilities for implementing such technology in the location where we plan to implement the system. On considering all these factors we will be able to come up with the right choice of communication protocol and ideal network architecture for communication.

So communication is a key part of automated systems and in this paper, we try to answer the questions like – Why do automated systems require communication? And what are the ideal communication protocol if the system is implemented in an urban or rural environment?

II. LITERATURE SURVEY

A. Urban development and the concept of Smart Cities

Several big cities across the globe are looking at using the smart city concept to improve their residents' living conditions and better use local infrastructure and resources [2]. Given the intricate architecture of Smart City settings, it's important to remember that communication technologies are at their core, allowing connectivity and data flow between the many components of the smart city. Wireless communications, given their capabilities, are Smart City enablers, allowing for quick and effective deployment and development. The emergence of many technologies that can be used in a range of circumstances is a clear trend in that sector.

In [3] Dalibor Dobrilović has presented the review and discussion on wireless technologies for enabling Smart Cities. This paper has also provided a comparative study of Smart City technologies. He Concluded that the range of technologies suitable to various contexts, a significant difference in the technology features, as well as the constant introduction of new technologies adds to the task's complexity.

In [4] Andrea Zanella et al provided an experimental study on the Padova Smart City, a practical implementation of IoT that has been implemented in the city of Padova. The major intent of Padova Smart City is to stimulate the before time use of Information and communications technology solutions and open data in the public sector. The targeted application is a system for public street lighting monitoring and gathering environmental data by utilising wireless nodes mounted on street light poles, equiped with different kinds of sensors and connected to the Internet through a gateway device. This device will capture useful environmental data such as CO levels, air temperature and humidity, vibrations, and noise. Measuring light intensity at each post is a simple but exact way of monitoring the correct operation of the public lighting system. IoT nodes are given unique IPv6 addresses that are suitably compressed using the 6LoWPAN protocol. IPv6/6LoWPAN allows each node to be accessed separately from anywhere on the Internet. Each node submits its data to a sink node, which acts as the sole contact point for extraneous nodes. Alternately, these nodes may run a CoAP server and broadcast their features and data, although this functionality isn't available in the testbed just yet. A gateway is required in both cases to connect the 6LoWPAN cloud to the Internet and do all of the previously stated transcoding.

In [2] Imad Jawhar et al state that in IoT, there are two popular ways of providing data access to objects. The first is to use multi-hop mesh networks with short-range communication between network nodes in the unlicensed band. The second option is to use licensed frequency band long-range cellular technology.

In [5] M. Centenario et al described the developing LowPower Wide Area Networks (LPWANs) paradigm for Internet of Things connectivity. This system is based on tens of kilometers of long-range radio connections and a star network architecture, in which each node is directly connected to the base station. According to the authors, the LPWAN paradigm should be designed to complement current IoT standards as an enabler of Smart City applications, which may substantially benefit from long-range connectivity, according to the experimental trials, which were conducted using LoRa™ technology.

B. Rural areas and smart agricultural practices.

Rural regions have a poor pace of development due to a lack of understanding and use of technology. Automation and emerging technologies can help to enhance the quality and lower the cost of providing services to remote areas. By overcoming physical distances and road or rail infrastructure limitations, Automated systems with effective communication facilities will enable rural populations to receive high-quality services. Major applications of automation in rural areas are in the field of agriculture and farming.

A wireless network implementation is a feasible option for rural towns looking to construct network infrastructure. Information services and socioeconomic growth are not available to rural residents due to a lack of network infrastructure[6]. Applications requiring huge amounts of data transmission, such as telemedicine, e-learning, and e-surveillance, will benefit from high-standard technologies with massive amounts of data transfer. High data capacity generally comes at a cost, which is why they are frequently implemented in metropolitan areas but are seldom seen in rural areas due to investment costs and user density [6].

In [7] Nurzaman Ahmed et al have proposed network architecture for monitoring and controlling agriculture and farms in rural areas. The authors have incorporated a WiLD network and Fog computing in the current WSN-based systems to span greater ranges with less delay. They have used a cross-layer-based MAC and routing system that adjusts traffic type and sets duty cycle accordingly to enhance latency and throughput across multi-hop IoT. They found that the MAC and routing solution for IoT obtained superior energy, delay, and throughput performance as a result of this trial. They also state that along with the Fog computing solution, technologies like IEEE802.11n/ac/ah with higher physical data-rate capacity can be employed to alleviate congestion in the proposed large-scale network.

III. ZIGBEE AS A COMMUNICATION TECHNOLOGY FOR AUTOMATED SYSTEMS IN URBAN AREAS

ZigBee is one of the numerous wireless communication technologies that may be used to construct a wireless network. When compared to other devices, these devices are small, have minimal power consumption, are inexpensive, and have a very short communication delay. ZigBee is a low-power, low-cost wireless network technology developed to enable low-power, low-cost, and low-data-rate applications. [8].

The reasons for suggesting ZigBee as an ideal communication technology for automated systems in urban areas are listed in the following points:

- ZigBee consumes lesser power when compared to the ideal wireless fidelity approach. In [9] Olaide O. Kazeem et al have performed a power consumption test of the low energy wireless protocols. In the test, it was found that the ZigBee consumed 12μA of current in sleeping mode and Wi-Fi consumed 30μA of current in sleeping mode. In the awake mode, ZigBee consumed 50mA while Wi-Fi consumed 245mA of Current. Thus ZigBee is less power consumption when compared to Wi-Fi.
- The support for mesh topology. As opposed to Wi-Fi, ZigBee is a mesh networking standard, which means that each node in the network is connected to the others. This eliminates the need to rely entirely on the router and endpoint [10]. The mesh topology will support the implementation of a Wireless Sensor Network using the three components – Coordinators, Routers, and End Devices. In [11] Y W Zhu et al have proposed a WSN system that is based on ZigBee technology for greenhouse. Wireless Sensor Networks have a broad range of applications in the concept of smart cities. WSNs are frequently utilized in our daily lives for a variety of purposes. Because of their cost-effectiveness and their rapid deployment, WSNs are made use of for securing smart cities by providing remote monitoring and sensing for different critical scenarios, such as battlefields, hostile environments, or areas subject to natural disasters such as volcano eruptions, earthquakes, and floods, or extensive accidents such as explosions of nuclear plant or chemical plumes [11]. In [11] the authors of the paper have provided a fraework where Wireless Sensor Networks (WSNs) are being made use for the purpose of remote sensing and monitoring in applications of the smart cities.

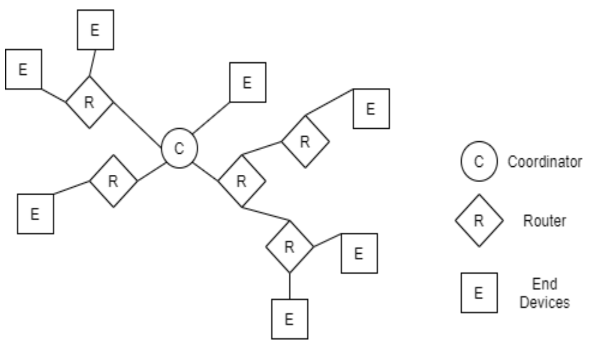

Figure 1: Mesh topology of ZigBee Devices

- ZigBee is scalable and thus allows new devices to be added to the network at any point. In [12] Parneet Dhillon et al state that up to 653356 devices can be connected to a ZigBee network. The distance between these devices can be as much as 50 meters, and each node in the network can relay data to other nodes. As a result, there is a very large network capable of traversing enormous distances. This factor is extremely important for Smart Cities that incorporate multiple devices.
- Diverse application domain. ZigBee has a diverse application domain. ZigBee is ideally used for devices having low power and low data rate requirements. ZigBee finds its application in healthcare. In [12] Omar S. Alwan et al demonstrate an effective ZigBee-based embedded system for wireless health care monitoring. ZigBee also has its application in the field of structural monitoring. In [13] Pooja R. Kamble et al have proposed a system to monitor the structural health of river bridges using ZigBee. They have designed a WSN to monitor the scour and vibrations of the river bridges.
- Security features. The ZigBee protocol employes the AES (Advanced Encryption Standard) encryption algorithm. The AES algorithm makes use of the higher length ley sizes - 128, 192 and 256 bits for the purpose of encryption, making it more robust against hacking. To break 128 bit, roughly 2^{128} tries are required. As a result, it is extremely difficult to hack, making it a very safe protocol.
- Open Standard. ZigBee is an open standards protocol with no or negligible licensing fees [14]. The advantage of using open standards is that it facilitates broader adoption. Open standards eliminate needless obstacles and provide everyone with access to the definitions of the format. Innovation and competitiveness are aided by open standard protocols. An additional advantage is that due to its open standards different vendors, manufacturers, and developers build on this protocol bringing in competitive prices to the products and giving it a better reach.

These reasons make ZigBee one of the viable options for automation and IoT in smart cities. An additional factor is the ease of availability of components. These components are easily available in urban cities, which adds to the advantage of using ZigBee.

IV. LORAWAN AS A COMMUNICATION TECHNOLOGY FOR AUTOMATED SYSTEMS IN URBAN AREAS

Due to the lack of infrastructure in rural areas, a lot of these communication technologies such as Wireless Fidelity (Wi-Fi) and ZigBee cannot be implemented effectively and efficiently. In such cases, making use of technologies such as LPWAN, especially LoRaWAN is much efficient and convenient. LoRaWAN is a revolutionary wireless communication technology with a great range and low power consumption [15]. The LoRaWAN open standard is a popular and successful low-power wide-area network (LPWAN) protocol.

The reasons for choosing LoRaWAN as an ideal communication technology for automated systems in rural areas are listed in the following points:

- LoRaWAN technology is thought to use less energy and can be powered for a long time by batteries [16]. LoRaWAN is an effective protocol of LPWAN (Low Power Wide Area Network) and one of the characteristics of LPWAN is that the nodes and the end devices consume low energy [17]. Due to the lack of infrastructure in the rural environment, this feature sums up to great advantage.
- The single LoRa Gateway device is designed to take care of thousands of end devices or nodes. According to the LoRa developer portal [18], throughout 24 hours, a single eight-channel gateway may accommodate a few hundred thousand messages. A gateway of this size may support about 10,000 end devices if each sends 10 messages each day. The network can support roughly 100,000 devices and one million messages if ten of these gateways are utilised. To expand capacity, all that is required is the addition of more gateways to the network.

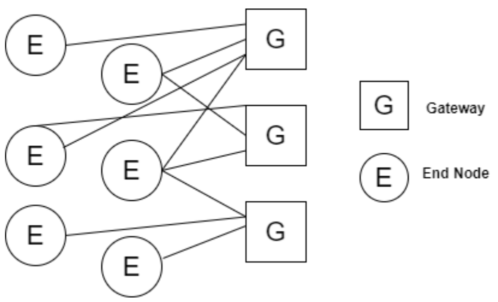

Figure 2: LoRaWAN Star Topology

- Larger coverage range. As the name suggests LoRa has Long-Range data links. Long-range communications are possible with LoRa, with distances of up to three miles (five kilometers) in urban areas and up to ten miles (15 kilometers) or more in rural regions (line of sight) [18]. This gives us the major reason for use of this technology in rural regions.
- There is no upfront licensing fee to utilize the technology because it operates on unlicensed frequencies. Lora operates in an unlicensed sub-GHz ISM band (900MHz in the USA and 860MHz in Europe). The advantage of using unlicensed bands is that anyone can make use of these frequency bands for free. The advantage is that this lowers the cost of implementation, enables industrial communication.
- Proven applications and examples are easier to convey the concept and idea. Agriculture is one of the most common practices in rural regions. In [19], Wenju Zhao et al have proposed a LoRa based smart irrigation system mainly composing of the LoRa smart irrigation module, a solenoid valve, and a hydroelectric generator. In [20] Henna David et al have worked on a smart irrigation system based on LoRa WAN. In [21], Sandra Sendra et al have presented a economical network that is based on LoRa technology that can detect fire danger and of a forest fire presence in remote areas. So the use of LoRaWAN for applications in the rural is already established.
- LoRaWAN is again an open standard that is governed by the LoRa open alliance. LoRaWAN is also secured with 128 bit AES key and a globally unique identifier both of which are used during the authentication process.

These reasons make LoRaWAN, LPWAN protocol a good choice for communication in rural regions.

V. CONCLUSION

This paper aims at understanding the need for communication in automated systems and recommending ideal communication technologies for automated systems installed in urban and rural areas. For urban regions, we have considered the concept and necessities of a smart city and recommended ZigBee as an ideal communication technology based on the premise and certain facts that constructively support its usage in smart cities. However, when it comes to the rural areas, the lack of infrastructure and the requirement of a long-range communication protocol calls for something that is both powers efficient. We have recommended LoRaWAN, LPWAN protocol as an ideal communication technology for automated systems in rural regions. These recommendations are based on the understanding and facts picked up from the literature survey supporting the cause.

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