IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

ISO 3297:2007 Certified ⁜ Impact Factor 8.102 ⁜ Peer-reviewed / Refereed journal ⁜ Vol. 12, Issue 5, May 2023

DOI: 10.17148/IJARCCE.2023.125158

ENHANCED IoT CONNECTIVITY: TRIPLE TIER CLUSTER BASED ROUTING IN MOBILE WIRELESS SENSOR NETWORK.

SREEKANTH V S[1], SHWETHA V[2]

Student, Sri Jagadguru Chandrashekaranatha Swamiji Institute of Technology Chikkaballapura, Karnataka, India[1]

Asst. professor Sri Jagadguru Chandrashekaranatha Swamiji Institute of Technology Chikkaballapura, Karnataka, India[2]

Abstract: Mobile Wireless Sensor Networks (MWSNs) are an important part of the Internet of Things (IoT), wheremany sensors are connected through wireless channels. However, there are challenges related to energy consumption, connectivity, scalability, and security in MWSNs. Adding mobility makes it even more challenging to find a good way to improve MWSN performance. This paper introduces a new routing protocol called "Triple Tier Cluster-Based Routing" (TTC-BR) that improves MWSN performance. It does this by dividing the network into virtual zones and using a triple-tier clustering approach. The virtual zones cover the entire network area using three levels: the main connectivity zone (MCZ), candidate cluster zone 1 (CCZ1), and candidate cluster zone 2 (CCZ2). The protocol selects the best sensor node to act as the Cluster Head (CH) for each zone.TTC-BR outperforms otherrouting protocols such as DDR, MCCA, LEACH-MEEC, and LEACH-M, and can improve network lifetime by 9% to48%. Our study suggests that TTC-BR is an efficient solution to improve the performance of MWSNs, particularly for large networks and many sensors.

Keyword: Mobile wireless sensor network (MWSN), cluster-based routing, cluster head (CH), virtual zone, energy-efficient.

I. INTRODUCTION

A mobile wireless sensor network (MWSN) is a network of mobile sensors that can move around and collect data about their environment. These networks are more flexible than traditional static sensor networks because they can adapt to different situations and deal with changes in their environment.MWSNs typically consist of small sensors with radio transceivers, microcontrollers, and sensors to detect things liketemperature, light, and humidity.

There are two main challenges for MWSN's: hardware and environmental constraints. Hardware constraints include limited battery power and the need for low-cost, simple components. Environmental constraints come from the shared communication medium and the changing topology of the network as sensors move around.

MWSNs rely on a base station or mobile sink to communicate with other networks, such as the Internet. Routing protocols are a particular challenge for MWSNs because of the large number of nodes and the need for efficient resource management to extend the network's lifetime. MWSNs are useful for many applications, such as environmental monitoring and surveillance, but require careful design and management to ensure they operate effectively.

II. BACKGROUND THEORY

❖ MOBILE SENSOR NODE ARCHITECTURE

In wireless sensor networks, sensor nodes are usually designed with sensors that can detect things like temperature, light, humidity, and pressure. They also have a microcontroller, memory, radio, and battery. But because they're small, they don't have a lot of storage, battery power, or processing capacity. Mobile sensor nodes are similar, but they have some extra features. They have units that can help find their location, move around, and generate power. The location unit helps identify where the sensor node is, the mobility unit allows the node to move around, and the power generator makes sure the node has enough energy to keep working. One example of a power generator is a solar cell.

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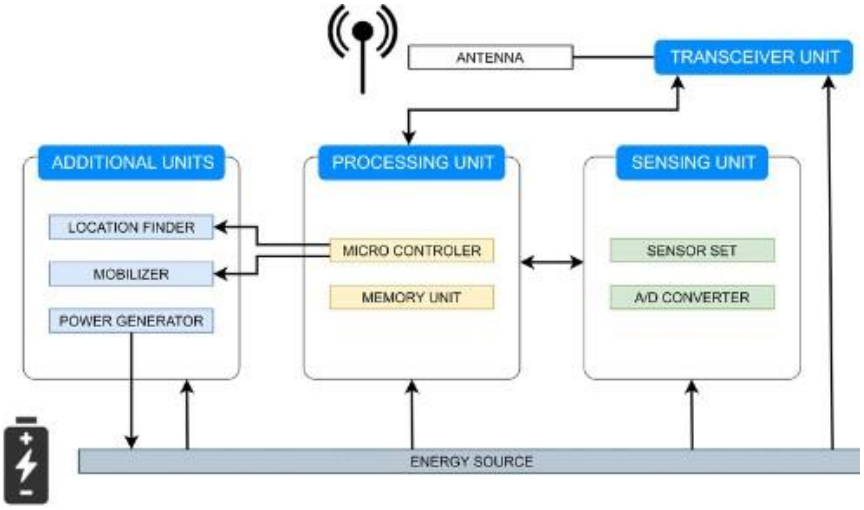

Figure 1:- Architecture of the Mobile Sensor node.

❖ NETWORK TOPOLOGY

In mobile wireless sensor networks (MWSNs), the way data is sent from the mobile sensors to the base station is very important. The topology, or the way the network is organized, plays a big role in making sure the data is transferred efficiently and reliably. Different network topologies are used to manage the group of sensors and ensure new sensors can join and leave the group easily. This helps to make sure the network is workingwell and not using too much energy. There are different types ofnetwork topologies that can be used, such as flat/unstructured, tree, cluster, chain, and hybrid, depending on the nature of the MWSNs. By choosing the right topology for the network, we can make sure it collects data effectively and performs well.

❖ ROUTING PROTOCOLS FOR MWSN's

Routing data in MWSNs can be challenging due to the lack of a fixed topology. Routing protocols in MWSNs draw inspiration from WSNs and MANETs, but often need to be adapted to handle the high frequency of topology changes and one-way communication requirements. One approach is to use location information to guide packet forwarding, as seen in protocols likeADSR, LEACH-M, ZBR, and GOR. Multipath protocols like DCBM can also provide robust routing. For high-speed MWSN applications involving UAVs, RASeR and LASeR useblind forwarding and gradient metrics to determine optimal packet forwarding paths. RASeR relies on regularlybroadcasting small beacon packets, while LASeR leverages existing geographical location information.

❖ CLUSTER BASED ROUTING

The Cluster Based Routing Protocol (CBRP) is a routing protocol commonly used in Mobile Ad Hoc Networks (MANETs). CBRP divides the network nodes into clusters in adistributed manner, with each cluster having a designated cluster head responsible for maintaining membership information within the cluster. This helps optimize resource consumption, balance network load, and support Quality of Service (QoS) requirements.

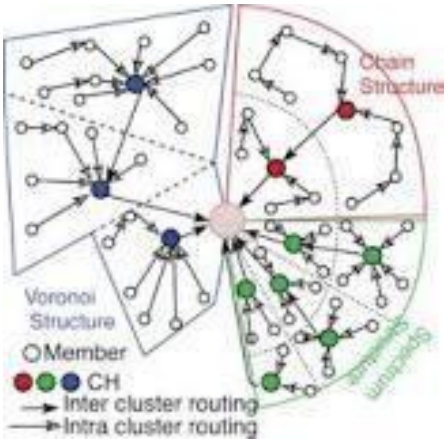

Figure 2:- Clustering of Nodes.

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Cluster-based routing is a widely used technique for routing in Wireless Sensor Networks (WSNs), including Mobile WirelessSensor Networks (MWSNs). This technique divides the network into groups called clusters, where each cluster is managed by a cluster head or leader node responsible for routing and data collection within that cluster. The cluster headis usually a node with more resources, such as higher energy or processing capabilities, than the other nodes in the cluster.

❖ **TRIPLE TIER CLUSTER BASED ROUTING** Triple-tier cluster-based routing is a network architecture thatis designed for large-scale IoT networks with many sensornodes. The network is divided into three tiers: the sensor nodetier, the sub-cluster head tier, and the cluster head tier. Thesensor nodes collect data and send it to the sub-cluster head,which aggregates it from a group of sensor nodes and sends itto the cluster head. The cluster head collects data from all thesub-cluster heads and sends it to the base station or sink node.The algorithm aims to reduce energy consumption by reducingthe distance between sensor nodes and the cluster head. Thesub-cluster head tier reduces the number of hops between thenodes and the cluster head, making the network more energyefficient. The algorithm is scalable and energy efficient butmore complex and may have higher overhead than the single-tier algorithm. It is designed to address the challenges ofmobile wireless sensor networks such as limited power,limited bandwidth, and node mobility.

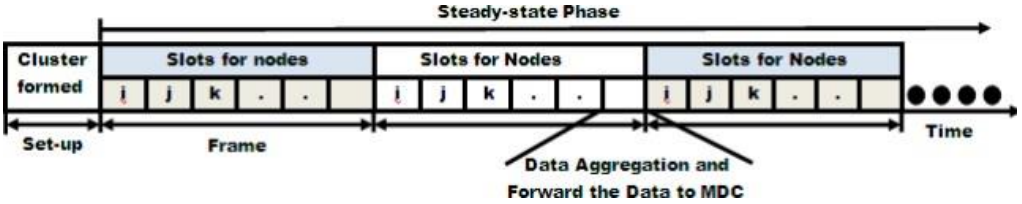

Figure 3:- Communication operation timeline.

III. TECHNOLOGIES IN TTCBRPROTOCOL

❖ **WIRELESS SENSOR NETWORK (WSN)TECHNOLOGIES**

Wireless Sensor Network (WSN) technologies, including ZigBee,Bluetooth Low Energy (BLE), and WirelessHART, are ideal for establishing communication between sensor nodes and other network components in Mobile Wireless Sensor Networks (MWSNs). These technologies are designed for low-power, short-range wireless communication and are suitable for transmitting data between sensor nodes and cluster heads or base stations

.

ZIGBEE

ZigBee is a wireless communication protocol that is commonly used in Wireless Sensor Networks (WSNs), including Mobile WSNs. It is designed for low-power, low-data-rate applications and can operate in the unlicensed 2.4 GHz frequency band. ZigBee is great for MWSNs because it has a range of up to 100 meters and can be used to connect multiple nodes to form a mesh network. The mesh network allows data to be transmitted over long distances by passing through intermediate devices. ZigBee isusually used in applications that require long battery life and secure networking, as it provides 128-bit symmetric encryption keys for security.

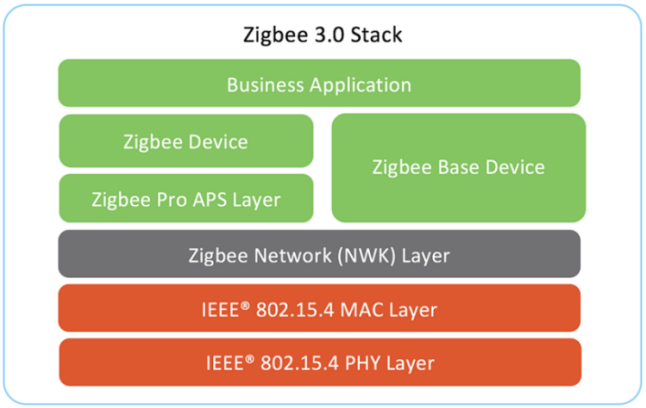

Figure 4 :- ZIGBEE Stack Model

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BLUETOOTH LOW ENERGY (BLE)

Bluetooth Low Energy (BLE) is a wireless communication protocol that is often used in mobile wireless sensor networks (MWSNs). It's designed for short-range, low-power communication, and can be used to connect multiple deviceswithin a limited range of up to 10 meters. BLE is commonly usedin mobile devices, such as smartphones and tablets, and was created specifically for IoT applications in industries such as healthcare, fitness, security, and home entertainment. It operates in the 2.4 GHz frequency band and uses a mesh network to connect devices.

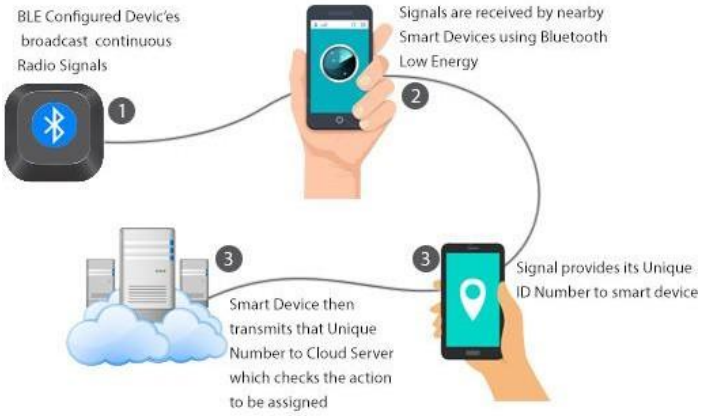

Figure 5 :- Bluetooth Low Energy (BLE) Technologies.

WIRELESSHART

WirelessHART is a wireless communication protocol that is used in industrial automation applications. It is based on the HART protocol and is designed to work in harsh environments. It operates in the 2.4 GHz frequency band and can transmit data up to 100 meters. WirelessHART is a reliable and robust protocol that can maintain compatibility with existing HART devices, commands, and tools. It uses mesh networkingtechnology, which makes it well-suited for mobile wireless sensor networks.

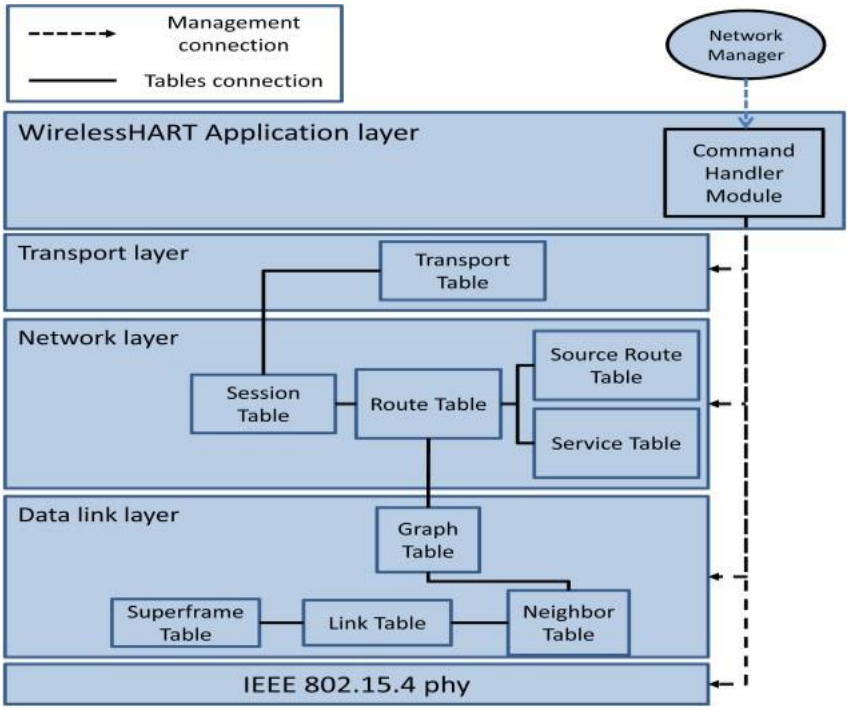

Figure 6 :- WirelessHART Protocol Stack.

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❖ MACHINE-TO-MACHINE (M2M)TECHNOLOGIES

M2M technology refers to the exchange of data between machines or devices without the need for human interaction. This technology is commonly used in various industries, such as smart homes, vehicle tracking, and supply chain management. M2M communication can be established through wired or wireless channels, and it allows devices to share information automatically and efficiently.

LONG-TERM EVOLUTION (LTE)

Long-Term Evolution (LTE) is a wireless communication standard that improves on previous mobile network technologies like GSM/EDGE and UMTS/HSPA by increasing capacity and speed. It achieves this by using a different radio interface and core network improvements. LTE is often used to refer to wireless broadband or mobile network technologies and is sometimes called 3GPP Long Term Evolution. The 3GPP is a group that works to develop these standards. LTE is also known as LTE Super 3G and LTE Super 4G.

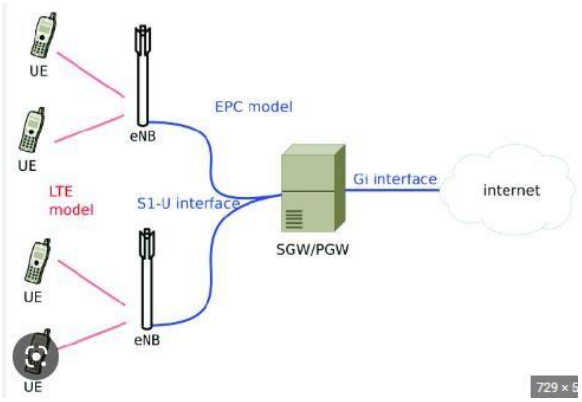

Figure 7 :- Long-Term Evolution (LTE) Architecture.

NARROWBAND IOT (NB-IOT)

NarrowBand Internet of Things (NB-IoT) is a technology designed to connect a large number of low-power IoT devices using cellular networks. NB-IoT operates on a narrow bandwidth, which means it requires less power and can penetrate deeper into buildings than traditional cellular networks. This makes it ideal for devices that need to be located indoors and require a long battery life. The technology uses a subset of the LTE standard to enable efficient and cost-effective communication between devices and base stations. In NB-IoT systems, specially designed devices and sensors collect information from their surroundings and transmit it to base stations or transmission nodes.

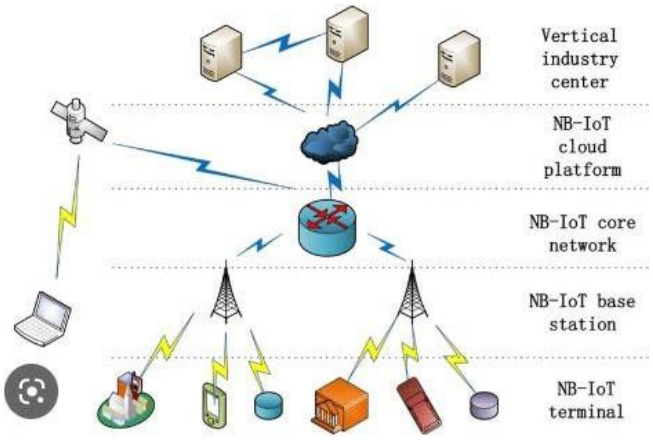

Figure 8:- Narrowband IoT (NB-IoT) Architecture.

❖ CLOUD COMPUTING TECHNOLOGIES

Cloud computing technologies, such as Amazon Web Services, Microsoft Azure, and Google Cloud, can be used to store and process the large amounts of data collected by MWSNs. Cloud storage solutions can store and manage the data,

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making it easier to access and analyze. Cloud-based data processing solutions can be used to perform complex data processing tasks that may be tooresource-intensive for the sensor nodes. Additionally, cloud- based machine learning solutions can be used to analyze and interpret the data and identify patterns and trends. Cloud-based integration solutions can integrate data from MWSNs with other data sources such as social media platforms or other IoT devices. Overall, cloud computing platforms provide a scalable and flexible solution for storing, processing, and analyzing the data collected by MWSNs.

Figure 9:- Cloud Computing Architecture.

❖ BIG DATA ANALYTICS TECHNOLOGIES

Big data analytics technologies like Hadoop, Spark, and Cassandra are useful for analyzing the data collected by MWSNs. These technologies can help extract valuable insights from the data and provide real-time feedback to users. Hadoopis a framework for storing and processing large datasets, Sparkis an engine for analyzing large datasets in real-time, and Cassandra is a distributed database system that can store and manage large datasets. Additionally, these technologies can create data visualization tools like charts and graphs to help users understand the data.

❖ SECURITY TECHNOLOGIES

Security technologies play a vital role in safeguarding the data generated by MWSNs. Encryption is one such technology that helps to protect the data by converting it into an unreadable format, making it difficult for unauthorized parties to access it. Digital signatures can be used to authenticate the sender of a message and ensure that the data is not tampered with during transmission.

Secure communication protocols such as TLS and SSL can be used to transmit data securely over the network. Access control mechanisms can be used to restrict access to data and ensure that only authorized users can access it. Intrusion detection systems can help to detect and prevent attacks by monitoring the network for suspicious activity.

Key management protocols are crucial for ensuring the security of MWSNs, as compromised keys can lead to unauthorized access to the data. Firewalls can be implemented at different levels of the network to protect against external attacks by filtering traffic based on predefined rules. Overall, these security technologies work together to protect the integrity of the MWSN and ensure the privacy of the data.

IV. METHOD

❖ WORKING PRINCIPLE

Triple tier cluster-based routing is a method used in mobile wireless sensor networks (MWSNs) to efficiently send data from mobile sensors to a central base station. The technique divides the network into three parts, each with a specific job andset of nodes.

The first part is the base station, which receives data from the mobile sensors and processes it. It communicates with the second part, which consists of cluster heads responsible for managing groups of sensors in their respective clusters. The cluster heads collect data from the mobile sensors in their cluster and forward it to the base station. The cluster heads

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also communicate with the third part, which is made up of the mobile sensors themselves.
This technique uses a hierarchical approach to efficiently route data from the mobile sensors to the base station. By using cluster heads as intermediaries between the sensors and the basestation, the number of hops required for data transmission is reduced. This results in lower energy consumption for the mobile sensors and less data being transmitted over the network.

❖ MECHANISM OF OPERATION

I. NETWORK INITIALIZATION

The network initialization phase is a vital step in setting up a triple tier cluster-based routing system in mobile wireless sensornetworks (MWSNs). During this phase, each sensor node selects a cluster head (CH) based on the strength of the signal they receive from available CHs. Once a sensor node selects a CH, it sends a join request message to the CH, which responds with an acknowledgment message, and the sensor node becomes part of the CH's cluster.

The CHs are then responsible for collecting data from sensor nodes in their cluster and transmitting it to the secondary cluster head (SCH), which manages the clusters, assigns roles to the CHs, and establishes communication between the clusters. In the initialization phase, the SCH broadcasts network topology information to all the CHs, and each CH updates its routing table with this information. The table includes the location and signal strength of the other CHs and paths to other clusters, which are used to route data to the SCH.

The network initialization phase is essential for successfully setting up the MWSN, as it enables the sensor nodes to connect tothe network and select their CHs. It also establishes communication and routing protocols among the CHs and the SCH, which is crucial for efficient data transmission and energy conservation in the network.

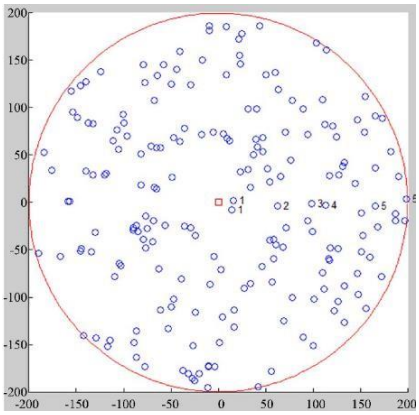

Figure 10:- Initialization of Network.

II. CLUSTER FORMATION

In the cluster formation phase of triple tier cluster-based routingin mobile wireless sensor networks (MWSNs), the secondarycluster head (SCH) helps the cluster heads (CHs) to form triple tier clusters. The SCH is responsible for managing the clusters, assigning roles to the CHs, and establishing communication between the clusters.

After the network initialization phase, each CH collects data fromthe sensor nodes in its cluster and transmits it to the SCH. The SCH then broadcasts a message to all the CHs, containing the network topology information, including the location and signal strength of the CHs, and paths to other clusters. The CHs update their routing tables accordingly.

The SCH selects a gateway node for each cluster, based on signalstrength and location. The gateway node collects data from the CHs and transmits it to the SCH. With the help of the SCH, the CHs form triple tier clusters and are assigned roles such as clustermanagement, data collection, and routing. The SCH also establishes communication between the clusters to enable theexchange of data between them.

The cluster formation phase establishes the hierarchical structure of the network and assigns roles to the CHs. The SCH manages the clusters and ensures efficient and reliable data transmission.

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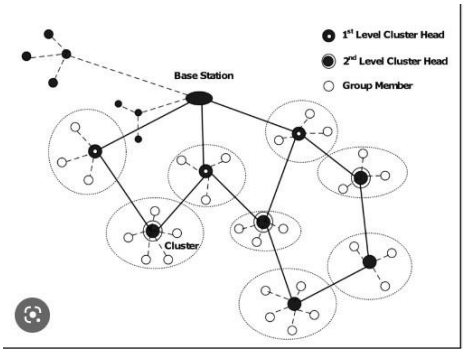

Figure 11:- Basic Architecture of Clustering.

III. DATA TRANSMISSION

In mobile wireless sensor networks (MWSNs), data transmission is an essential phase that involves sending data from the sensor nodes to the CHs, gateway nodes, and SCH. After forming triple tier clusters, the SCH assigns roles to the CHs and enables communication between the clusters to exchange data.

The data transmission process begins with low-power wireless communication technologies like ZigBee or Bluetooth Low Energy (BLE) used to send data from the sensor nodes to the CHs. The CHs then send the data to the gateway node, which uses long-range wireless communication technologies such as Wi-Fi or cellular networks to send the data to the SCH.

To make data transmission efficient, the SCH may use techniques like data aggregation, compression, and routing. Data aggregation combines multiple data packets into one, reducing the amount of data transmitted, which saves energy. Data compression reduces the data size using algorithms such asHuffman coding, which saves bandwidth. Routing selects the best path for data transmission based on factors like distance, signal strength, and congestion.

After receiving the data, the SCH stores it in cloud computing platforms such as Amazon Web Services (AWS), Microsoft Azure, or Google Cloud, where big data analytics technologies like Hadoop, Spark, or Cassandra analyze it to provide useful insights.Overall, the data transmission phase is crucial for the efficient and reliable transmission of data in MWSNs. The use of low-power wireless communication technologies, data aggregation and compression, and efficient routing techniques can conserve energy and bandwidth, leading to a more reliable network.

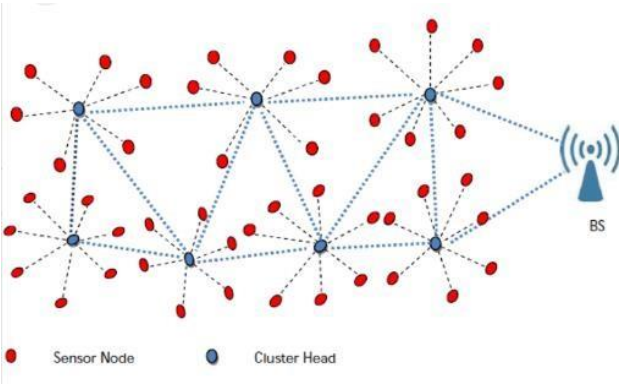

Figure 12:- Cluster-Based Data Transfer in MWSN's.

IV. ROUTING PROTOCOL

In mobile wireless sensor networks, the routing protocol is crucial in determining the best way to transmit data between the nodes. There are two types of routing protocols: proactive and reactive. Proactive protocols maintain routes in advance, while reactive protocols establish them only when needed. In triple tier cluster-based routing, the hybrid protocol is commonly used, which combines the benefits of both proactive and reactive protocols. The hybrid protocol maintains stable routes between cluster heads and gateway nodes using a proactive protocol. When sensor nodes have data to transmit, they use a reactive protocol to request a route to their cluster head, which forwards it to the gateway node and then to the SCH. The SCH selects the best path and sends the route back to the sensor node,which then transmits the

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data to the cluster head. This method conserves energy and bandwidth by maintaining stable routes and establishing them only when necessary.

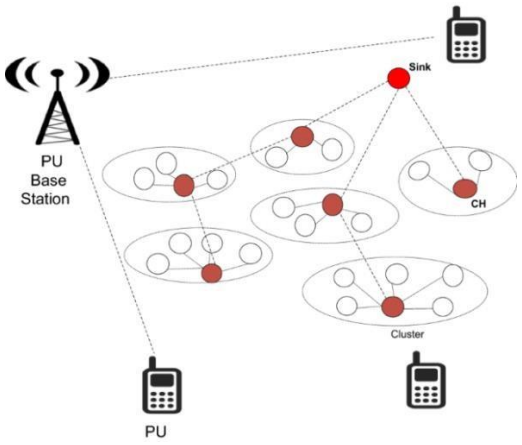

Figure 13:- Optimized Transmission Distance.

V. ADVANTAGES

❖ **Efficient Use of Energy:** Triple-tier cluster-basedrouting significantly reduces energy consumption and extends the lifetime of the network.

❖ **Improved Reliability:** The use of multiple tiers of nodes in this protocol improves the reliability of data transmission and reduces the likelihood of data loss.

❖ **Dynamic Network:** Triple-tier cluster-based routing is dynamic and can adapt to changes in the network topology, making it suitable for mobile wireless sensor networks.

❖ **Reduced Overhead:** Dividing the network into smaller clusters and assigning cluster heads to manage them reduces the overhead of network management.

❖ **Reduced routing delay:** Triple-tier cluster-based routing reduces routing delay by using shorter paths for data transmission.

❖ **Reduced network traffic:** The protocol reduces network traffic by using data aggregation at the cluster heads. This reduces the amount of data that needs to be transmitted, which helps to conserve energy and reduce network congestion.

VI. APPLICATIONS

❖ **Smart Grid:** Triple-tier cluster-based routing can be used to monitor and control power generation and distribution systems, making it useful for managinglarge-scale smart grid networks.

❖ **Industrial IoT:** In Industrial Internet of Things (IIoT) applications, the protocol's energy efficiency and load balancing capabilities make it well-suited for large- scale IIoT systems.

❖ **Public Safety:** In public safety applications, triple-tier cluster-based routing can be used to provide critical communications during emergency situations, thanks to its reliability and energy efficiency.

❖ **Smart Cities:** Triple-tier cluster-based routing can be used to monitor and manage urban infrastructure, making it well-suited for large-scale smart city systems.

❖ **Environmental Monitoring:** Triple Tier Cluster Based Routing can be used to monitor environmental conditions such as air quality, water quality, and weather patterns, making it useful for a wide range of environmental monitoring applications.

VII. CONCLUSION

Routing protocols are essential for managing failures and changesin network topology in mobile wireless networks, while minimizing energy consumption. Clustering is a useful approach
for topology management in large-scale mobile wireless networks. However, clustering algorithms face significant challenges in managing intra-cluster and inter-cluster transmissions to achieve high packet delivery ratios with minimum energy consumption. The optimal cluster formation iscritical to maximizing network lifetime. In this paper, we discussed the differences between cluster routing categories andfocused on block-based cluster routing protocols for mobilewireless networks.

In this study, we compared single and multi-hop routing protocols for mobile wireless networks and found that the MDC maximum residual energy LEACH routing protocol outperformed the LEACH and Hybrid Multi-hop LEACH routing

DOI: 10.17148/IJARCCE.2023.125158

protocols in terms of energy consumption, network lifespan, traffic received, packet loss ratio, channel access, and end-to-end delays. Twenty different protocols were analyzed based on basic information, network simulation, and performance parameters specific to mobile wireless networks.

There have been considerable research efforts in designing routing protocols to improve energy efficiency and data reliability in mobile wireless networks, with a focus on limiting message transmissions. However, there are still energy-efficientprotocols that require further study in the future. Mobile wireless networks have numerous applications, such as transportation, public safety, and disaster response, where robust, energy-efficient, and reliable protocols are necessary. In conclusion, this study highlights the importance of robust, energy-efficient, and reliable protocols in various applications and emphasizes the need for further research to develop energy-efficient protocols for mobile wireless networks

VIII. FUTURE SCOPE

Machine learning-based routing: Machine learning-based routing is an emerging area of research that can improve the performance and efficiency of triple-tier cluster-based routing inMWSNs. By using machine learning algorithms, routing decisions can be made based on historical data, network traffic patterns, and other parameters. This approach can adapt to changing network conditions and optimize routing decisions for better performance.

Multi-objective optimization: Multi-objective optimization is another area of research that can improve the performance of triple-tier cluster-based routing in MWSNs. By considering multiple objectives, such as energy efficiency, network lifetime,and packet delivery ratio, routing decisions can be optimized forbetter overall performance. This approach can help to balance conflicting objectives and achieve a better trade-off between different metrics.

❖ These two are the most promising areas of research, machine learning-based routing and multi-objective optimization. Machine learning-based routing can adapt to changing network conditions and optimizerouting decisions based on historical data and other parameters, which can result in better performance and efficiency. Multi-objective optimization can balance conflicting objectives, such as energy efficiency, network lifetime, and packet delivery ratio, andachieve a better trade-off between different metrics, which can improve the overall performance of the network. However some of the other research areas areincluded below:

Dynamic cluster formation: The future of triple-tier cluster- based routing in MWSNs may focus on dynamic cluster formation, where clusters are formed and re-formed based on the mobility of sensor nodes. This approach can improve network lifetime and energy efficiency by adapting to changing network topologies.

QoS-aware routing: Future research on triple-tier cluster-basedrouting in MWSNs may also focus on quality-of-service (QoS)aware routing, which ensures reliable and timely delivery of data packets with specific requirements, such as low latency, high throughput, or low energy consumption. QoS-aware routing can improve the performance of MWSNs in applications such ashealthcare, where timely delivery of data is critical.

IX. ACKNOWLEDGMENT

The authors thank the Principal, HOD and **Prof.Shwetha V**, Electronics and communation department, SJC instute of technology, Chikkaballapur for their support and encouragement for carrying out this paper.

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