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Revolutionizing 5G Networks: A Synergy of Routing, Clustering, and Energy Optimization for Unprecedented Performance and Extended Lifespan

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Abstract:

The concept of revolutionizing 5G (Fifth Generation) networks through a synergy of routing, clustering, and energy optimization is indeed a promising approach to enhancing the performance and lifespan of wireless networks. Exciting changes will occur in the physical, digital, and biological worlds over the next ten years. Although the needs for Beyond 5G (B5G) are not yet fully understood, an effort has been made to stratify 5G progression and B5G. This work highlights the focus on revolutionizing 5G networks through the integration of routing, clustering, and energy optimization techniques. By combining these methodologies, this research work aims to address the complex challenges in 5G networking, such as efficient data routing, resource allocation, and energy consumption. The objective is to achieve both exceptional performance and an extended lifespan for these networks. The proposed work holds promise for significantly enhancing the capabilities of 5G networks, resulting in improved user experiences, optimized resource utilization, and prolonged network lifespan. In order to completely meet the most stringent 5G standards, such as stratification, or deconstruction into existing technologies, will comprise technology scenarios of 5G evolutions. Wireless sensor networks (WSNs), which offer essential data collecting and monitoring capabilities, are made up entirely of 5G networks. These methods are designed specifically for use in 5G networks to increase the network's lifespan and overall performance. For 5G networks, routing and clustering techniques from WSNs can be modified and optimized to increase energy efficiency and prolong the network lifetime in 5G networks.

***Keywords**: 5G networks, Beyond 5G (B5G), Clustering, Energy Consumption, Energy Conservation, energy optimization technique, Network Lifetime, Optimization, Routing, Wireless Sensor Networks (WSNs).*

1. Introduction:

The progression from 5G to B5G represents a continuous evolution in wireless technology to address the ever-expanding demands of our increasingly connected world. The stratification and exploration of candidate technologies within the 5G framework serve as building blocks for the development of more advanced and specialized wireless communication systems in the future. These advancements will play a crucial role in shaping the way we connect, communicate, and interact with the physical, digital, and biological aspects of our world in the coming years [1].

Indeed, the next decade promises to bring about exciting changes in the physical, digital, and biological realms, particularly in the field of telecommunications and wireless technology. Let's delve into the concepts you mentioned regarding the evolution of 5G and the emergence of Beyond 5G (B5G) technologies [2]:

i. **5G Progression:** 5G, the fifth generation of wireless technology, represents a significant leap forward in wireless communication. It provides faster data speeds, lower latency, and more reliable connectivity compared to its predecessor, 4G LTE. As 5G technology continues to mature, it is expected to undergo several evolutions or enhancements to fully meet its potential and address various use cases.
ii. **Stratification of 5G:** This term refers to the breakdown or division of 5G technology into different components or aspects. This stratification is essential for understanding and optimizing the different elements of 5G technology [3].
iii. **Candidate Technologies:** To achieve the most stringent 5G standards and address diverse use cases, the development of 5G technology involves exploring various candidate technologies. These technologies may include advancements in hardware components (e.g., antenna technology, semiconductor materials), software

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(e.g., network management and optimization), and communication protocols.

iv. **Technology Scenarios of 5G Evolutions:** The evolution of 5G involves envisioning different scenarios or pathways for its development. These scenarios may be based on the specific needs and use cases that arise over time. For example, scenarios could include enhancements for autonomous vehicles, industrial automation, augmented reality, or the Internet of Things (IoT).

v. **Beyond 5G (B5G):** The B5G, often referred to as 6G, represents the next phase in wireless communication technology. While the exact specifications and use cases for B5G are not fully understood yet, it is expected to build upon the foundation of 5G and introduce even more advanced capabilities. This may include terahertz frequency bands, faster data rates, ultra-low latency, and support for emerging technologies like quantum communication.

The progression from 5G to B5G represents a continuous evolution in wireless technologies to address the ever-expanding demands of our increasingly connected world. The stratification and exploration of candidate technologies within the 5G framework serve as building blocks for the development of more advanced and specialized wireless communication systems in the future [4]. These advancements will play a crucial role in shaping the way we connect, communicate, and interact with the physical, digital, and biological aspects of our world in the coming years.

2. **Literature Review**:

The development of 5G networks has been a major milestone in the telecommunications industry, promising unprecedented performance and capabilities for a wide range of applications, from enhanced mobile broadband to Internet of Things (IoT) connectivity. To achieve the full potential of 5G networks, researchers and engineers have been exploring innovative approaches that involve routing, clustering, and energy optimization. This literature review will provide an overview of the key concepts and recent advancements in these areas, highlighting their synergy and potential to revolutionize 5G networks.

The concept of revolutionizing 5G networks through a synergy of routing, clustering, and energy optimization is indeed a promising approach to enhancing the performance and lifespan of wireless networks. Let's break down how each of these elements contributes to this revolution:

2.1 **Routing in 5G Networks**:

Routing in wireless networks refers to the process of determining the optimal path for data packets to travel from a source to a destination. In 5G networks, which are expected to support a wide range of applications with varying requirements, efficient routing is crucial. By optimizing routing algorithms, you can minimize packet latency, reduce congestion, and ensure that data flows smoothly through the network. This is especially important for applications like real-time video streaming, online gaming, and IoT devices that demand low latency and high reliability. Routing plays a critical role in the efficient transmission of data in 5G networks. Traditional routing protocols may not be suitable for the unique challenges presented by 5G, such as ultra-low latency and massive device connectivity. Researchers have been exploring new routing algorithms and strategies to address these challenges.

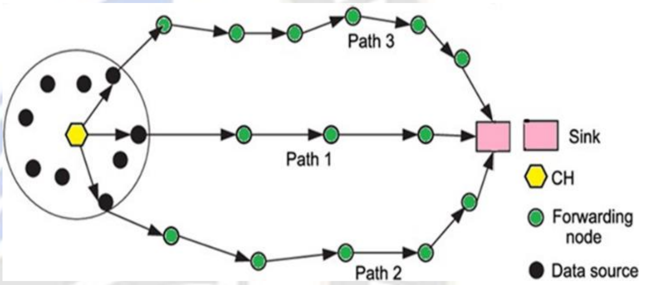

Figure 1: Diverse Routing Schemes in 5G Networks

2.1.1 **Network Slicing**:

Network slicing is a concept that allows the creation of virtualized, isolated network segments within a single physical network. It enables customized routing and service provisioning for different applications, optimizing network resources [5, 6].

2.1.2 **Machine Learning-Based Routing:**

Machine learning techniques have been applied to optimize routing decisions dynamically. These algorithms adapt to changing network conditions and traffic patterns, improving overall network efficiency [7, 8].

2.2 Clustering in 5G Networks:

Clustering involves organizing network nodes into groups or clusters. This can help improve network management and reduce overhead. In 5G networks, clustering can be particularly valuable for load balancing and resource allocation. By grouping nodes based on their proximity or

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functional similarity, you can optimize the use of available resources and minimize interference. Clustering can also facilitate the deployment of edge computing, where data processing occurs closer to the source of data, reducing latency for critical applications. Clustering techniques have gained attention in 5G networks to manage the massive number of devices and reduce complexity. Clustering involves grouping devices into clusters, with one device acting as a cluster head responsible for coordination. This approach can enhance scalability and reduce control overhead.

2.2.1 **Dynamic Clustering**:

Dynamic clustering mechanisms allow devices to join or leave clusters as needed, adapting to changing network conditions and ensuring load balancing [9, 10].

2.2.2 **Energy-Efficient Clustering**:

Clustering can help save energy by enabling sleep modes for devices within a cluster when their services are not required, thus extending the lifespan of battery-powered devices [11, 12].

2.3 Energy Optimization in 5G Networks:

Energy efficiency is a critical concern in wireless networks, as it impacts the operational cost and environmental footprint of the infrastructure. 5G networks are expected to support a massive number of devices, including IoT sensors and smart devices [13 - 15]. Energy optimization techniques, such as dynamic power management, sleep modes for idle devices, and energy-efficient hardware designs, can significantly extend the lifespan of network components and reduce operational costs. Additionally, renewable energy sources and energy harvesting technologies can be integrated into 5G network infrastructure to make it more sustainable.

Energy optimization is crucial for ensuring the longevity of battery-powered 5G devices, particularly for IoT applications. By synergizing these three elements—efficient routing, intelligent clustering, and energy optimization—5G networks can achieve several important outcomes: Techniques to reduce energy consumption include:

2.3.1 **Power Management:**

Power-efficient hardware components and intelligent power management strategies are essential for prolonging the battery life of 5G devices [16 - 19].

2.3.2 **Energy-Efficient Protocols**:

The development of energy-efficient communication protocols, such as low-power wide-area networks (LPWANs), has been a significant focus, especially for IoT applications with long-range, low-data-rate requirements [20, 21].

2.4 Synergy and Integration:

The synergy between routing, clustering, and energy optimization is critical for achieving the proposed performance and extended lifespan in 5G networks [22 - 26].

2.4.1 **Energy-Aware Routing**:

Routing protocols can take into account the energy constraints of devices, ensuring that energy is conserved while data is efficiently transmitted [27].

2.4.2 **Clustering for Energy Efficiency**:

Clustering can be used to organize devices into energy-efficient groups, optimizing the usage of energy resources.

2.4.3 **Dynamic Adaptation**:

A key advantage of the synergy is the ability to dynamically adapt to changing network conditions, traffic patterns, and device requirements.

2.5 **Extended Network Lifespan**:

Energy optimization techniques can prolong the operational lifespan of network equipment and reduce maintenance costs, ensuring the long-term sustainability of 5G infrastructure [28].

2.6 **Scalability**:

These strategies can also make 5G networks more scalable, allowing them to accommodate the increasing number of connected devices and emerging applications.

2.7 **Improved Quality of Service (QoS)**:

Effective routing and clustering can lead to better QoS for end-users, ensuring that they have a seamless experience when using 5G services.

2.8 **Enhanced Performance**:

Optimized routing and clustering strategies can ensure that data reaches its destination quickly and reliably, meeting the stringent performance requirements of 5G applications.

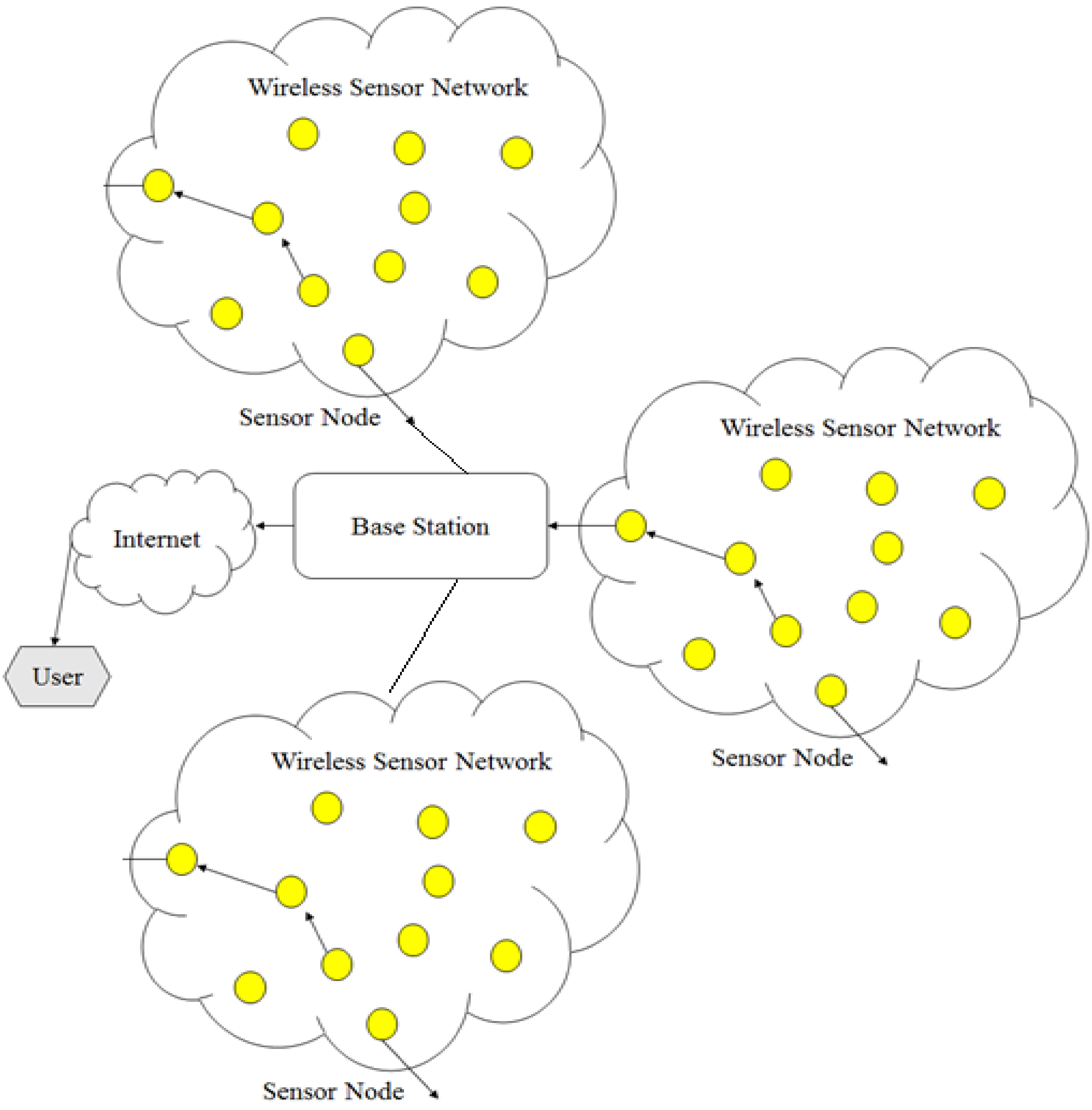

Figure 2: Basic Structure of 5G Network

The revolutionizing of 5G networks through the synergy of routing, clustering, and energy optimization holds great promise for achieving unprecedented performance levels while ensuring the long-term sustainability of these networks. This approach is essential to meet the diverse and evolving requirements of 5G applications and to prepare for the future evolution of wireless communication technologies beyond 5G. The literature reveals that the synergy of routing, clustering, and energy optimization holds immense potential to revolutionize 5G networks. These strategies address the unique challenges of 5G, such as ultra-low latency, massive device connectivity, and energy constraints, ultimately leading to unprecedented performance and extended lifespan for the next generation of wireless communication systems. Researchers and engineers continue to explore and refine these concepts to fully realize the capabilities of 5G networks in various applications.

3 PROPOSED WORK:

The proposed protocol is designed to select the neighbor nodes, which were supposed not to drop the data packets

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due to any constraint it may either be energy or buffer. To elaborate on the network lifetime and performance, multiple matters were combined in a distinct procedure for calculating the routing pathway among the transmission bodies. At all intervals of time, every node desires to estimate its position concerning energy, in the wireless network. Furthermore, this work computes proactively as, the utmost amount of data information packet it can operate (accept, process, and broadcast) within the existing amount of power. Additionally, within the wireless net, every node must need to analyze its stack management condition. Furthermore, in this exertion, it is also reactively computed depending on a predefined threshold value, as the available queue at the node buffer is less than or larger than the threshold value. To eliminate a node to turns out to be a bottleneck intermediate node two factors are used thereby mitigating the loss of the packet. The methodology flow chart of the work is shown in Figure 3 given below.

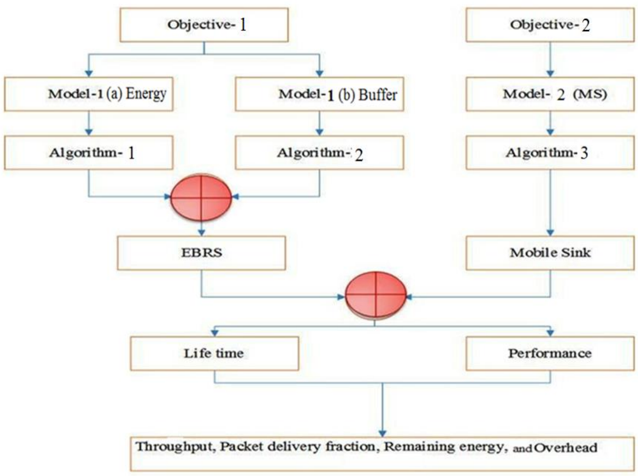

Figure 3: Flow Chart of the Proposed Work

The drop in the information packet due to node constraint 'energy' can be mitigated by an intermediary node and can be overwhelmed through multi-objective optimization progression [29]. To facilitate the capability of the node to optimize the utmost packets and can be handled using an intermediary node within its limits of existing residual energy. Let's assume that, an intermediary node outfitted through a battery capability of (E) joules, also it can process the utmost number 'n' of data packets within its present power limits.

3.1 Multi-objective development:

1. Node power: Necessary power to course the data packet

Let us think, for processing an individual data packet; the power consumed by an intermediary node is 'P_1' and it is measured through equation 1.

$$E(P_1) = E_r(P_1) + E_p(P_1) + E_t(P_1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

Where,
$E_r(P_1)$ = *energy require to receive the packet* 'P_1'
$E_p(P_1)$ = *energy require to process the packet* 'P_1'
$E_t(P_1)$ = *energy require to transmit the packet* 'P_1'

Now, after dealing out 'P_1' data packet the residual power of the node is specified by equation 2.

$$E(residual) = E - E(P_1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

After processing the data packets, the residual power of the node is given by a multi-dimensional (two) array, as given below.

$$[P_i, E(residual)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

In the above equation, $i = numberofpackets$
$E(Residual)$ = Remaining Energy of the Node

Calculating the capacity to optimize the utmost packet that can be processed through an intermediary node within its existing power is specified in equation 4.

$$K[P_i, (Residual)E] = \text{Max}\,(K[P_{i-1}, (Residual)E],\ K_i + K[P_{i-1}, (Residual)E]) \ldots (4)$$

$$\forall\ 1 \le P_i n$$
$$and$$
$$0 \le (residual) \le E$$

Here, 'K' is a two-dimensional constant, [P_i, ($Residual$)], providing the ability to optimize the utmost packets which can be processed by the intermediary node within its residual energy.

4 Proposed Methodology:

4.1 Proposed Routing Protocol

The proposed protocol is an extension of the existing energy-efficient routing protocol designed for a wireless network, i.e., LEACH. The brief discussion about the LEACH protocol is explained as follows, and further, the proposed model is explained.

The routing protocols used in wireless networks are cluster-based. The main intention behind it is, to select the top-quality wireless nodes randomly as a cluster head. Further, these selected nodes are used as the router to the destination

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node. The cluster head node's choice is done based on the node's residual energy in that particular period. The formula for finding the threshold value of energy for selecting the cluster head is given by $T(n)$, it can be determined by the following formula,

$$T(n) = \begin{cases} \frac{p}{1-p\times[r \bmod(1/p)]}, n\in G \\ 0, others \end{cases} \quad \ldots$$

Where, p = *needed percentage of power to become a cluster head*, r = *existing rout*, G = Number of wireless nodules.

Once cluster formations are done, then, the head nodes create a TDMA schedule. This will issue a notice to every node when it can pass on the data packet to the head of the particular cluster. Finally, the heads of the particular cluster gather data packets and transmit them to the destination node.

For communicating with the intermediate wireless nodes in the network, the model used is RWMM. Thus, the mobile nodes stay at a particular place near the existing intermediate node for some time interval to communicate and, afterward change their location by using the RWMM model. After that time interval, the node changes the position to other intermediate nodes based on the status of the node. Initially, the sink selects the intermediate node randomly moves closer toward it, and communicates through it. Then, the sink node selects the new intermediate node for communication and moves toward it according to the RWMM model theory.

4.2 Energy-Load Aware Routing Protocol for 5G Networks:

4.2.1 Network Model:

We are assuming that the wireless nodes were dispersed with one movable destination node in the sensor field. Every sensor node has constrained recourses such as energy and buffer and they are static and cannot move after the deployment. While the movable sink node has unconstrained energy and an adequate buffer for communication. The wireless nodes identify their position through GPS. In this scenario, the initial location of the movable destination node is not considered [30].

4.3 Energy and Load Awareness:

The proposed protocol aims to decide the neighbor nodule to a mobile destination based on its buffer and energy status. So, the intermediate node should not drop the data packets and should not exhaust. At this stage, we are considering two parameters in the single process for calculating the routing path between the communication nodes. Primarily, the Cluster head must compute the status regarding energy and buffer (load). In this proactive computation is done to get the utmost number of data packets the head can process within its accessible power. Secondarily, each wireless node has to calculate its load position in the network [31]. In this, reactive computation is done to find out the accessible queue at the node buffer, in fewer or greater, as per the predefined threshold rate. These factors were used to reduce the data packet loss and keep a wireless node from becoming a bottleneck intermediate node.

Let's assume that, the power consumed for processing one data packet by an intermediate node is $'P_1'$. The total energy used by an intermediate wireless node is computed by, equation 9.

$$\boldsymbol{E(P_1) = E_r(P_1) + E_p(P_1) + E_t(P_1)} \ldots\ldots\ldots\ldots\ldots\ldots \textbf{(9)}$$

Where,
$\boldsymbol{E_r}(P_1)$ = Energy Required to Receive the Packet $'P_1'$
$\boldsymbol{E_p}(P_1)$ = Energy Require to Process the Packet $'P_1'$
$\boldsymbol{E_t}(P_1)$ = energy Require to Transmit the Packet $'P_1'$

Furthermore, the residual energy of the wireless node after dealing with the packet
$'P_1'$ is shown in the equation 10.

$$\boldsymbol{E(residual) = E - E(P_1)} \ldots\ldots\ldots\ldots\ldots\ldots \textbf{(10)}$$

Finally, the capability of the intermediate node, to optimize maximum data packets can be processed in its existing energy and it can be achieved by entries of the arrays (two-dimensional), which are shown under.

$$\boldsymbol{[P_i, E(residual)]} \ldots\ldots\ldots\ldots\ldots\ldots \textbf{(11)}$$

Where, $i = 1, 2, \ldots$. *Number of Packets*
$E(residual)$ = *residual Enrgy Required by the Node to Process the Packet*

Also, the calculation of the capability to optimize the utmost data packets can be processed by the intermediary wireless node within its present power status, which is shown under

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the below consideration.

$$\forall \ 1 \leq P_i n$$
$$and$$
$$0 \ \leq E(residual) \leq E$$

Where, $[P_i, \ E \ (residual)]$, provides the capability of the intermediary wireless node to optimize maximum packets and process them within its available power.

4.4 Performance in Dynamic Environment:

The following performance metrics were considered to calculate the performance,

I. **Throughput**: A performance metric of the network to analyze how many data packets are transmitted in a particular amount of time from source to destination.

II. **Delay**: Delay is a very important metric in the wireless network to measure how much is taken by the data packets to receive at the sink node transmitted from the base node.

III. **Overhead**: The overhead can be defined in the manner that, the relation between the number of control packets (pathfinding packets, and route maintaining packets) to authentic information data packets transmitted within the wireless network.

The network simulation parameters were made known in the table below

Table 1: Simulation parameters

Sr. No.	Network Parameters	Values
1	Time for Simulation	1000 seconds
2	Nodes used (Number)	10-100 units
3	Nature of Link Layer	Logical Link/ LTE and NR modules provided by NS-3
4	IEEE Standard for MAC Protocol	802.11/3GPP NR
5	Type of Communication (Radio)	Two Ray Ground Propagation Loss Model
6	Queue Style	Drop Tail Queue
7	The protocol used for Routing	Proposed/Mobile IPv6
8	Traffic Methodology	Proposed/Mobile IPv6
9	Specified Area of the Network	1500m x 1500m
10	Type of Mobility	Random Waypoint Mobility Model

For calculating the performance of the proposed routing protocol, Network Simulator (version NS2.34) is used. The outcomes were compared with the present routing protocols. This simulator

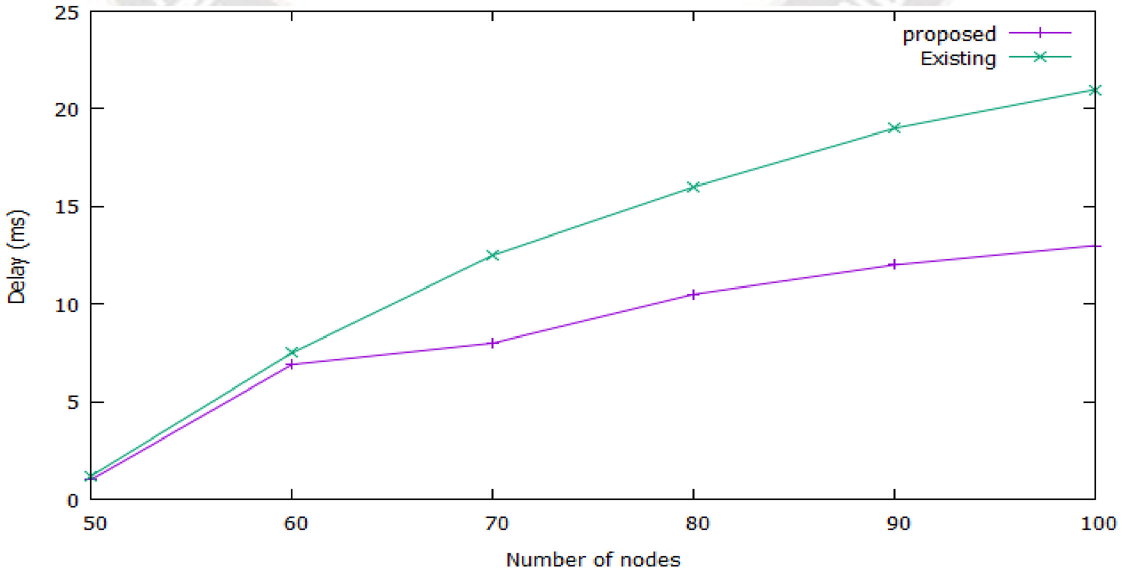

Figure 4: Delay Comparison

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evaluates the performances of different metrics like routing overhead, time delay, as well as the throughput of the wireless network. In the simulation part, the time for simulation is assumed as 1000s with different three scenarios with different performances. Furthermore, for verification of the results, the assumptions are made that there is an uneven quantity of nodes with the mobility model of Random waypoint mobility. The source power for every node is assumed as of 10j and the period of 20 m/s is assumed as pause time. The radio range for communication is fixed at 250m and the MAC IEEE 802.11 is considered with a data rate card of 2 Mbps. While talking about the transmitting and receiving power, these are kept as 300mW (receiving power) and transmission power is 600mW. Finally, the packet size is considered in bytes of 512 values, and the traffic in the network is considered as CBR.

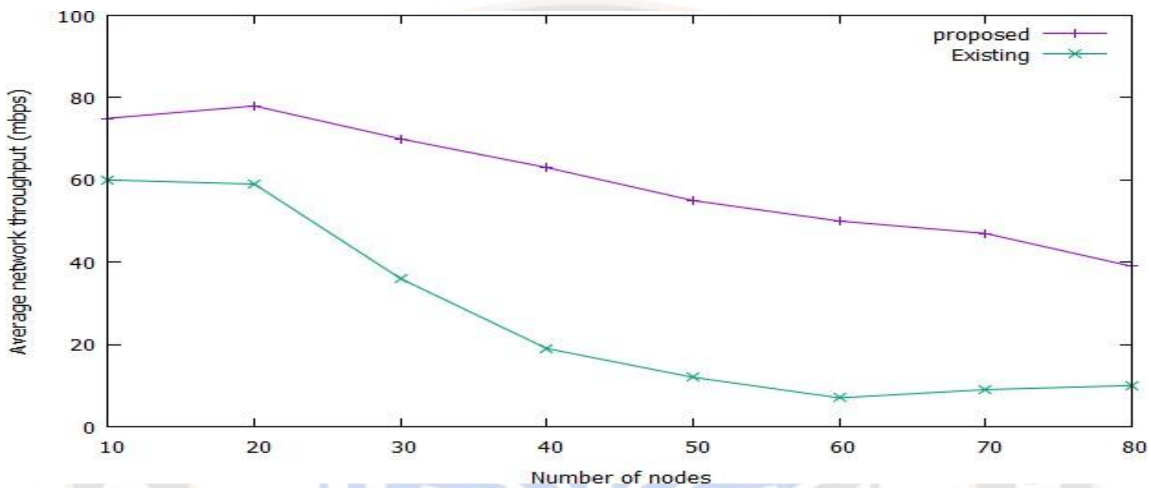

Figure 5: Throughput Comparison

All the above results show that the projected work outperforms in terms of network lifetime enhancement, network delay minimization, and throughput. Additionally, it mitigates the loss of data information packets by extending the energy efficiency of the wireless network.

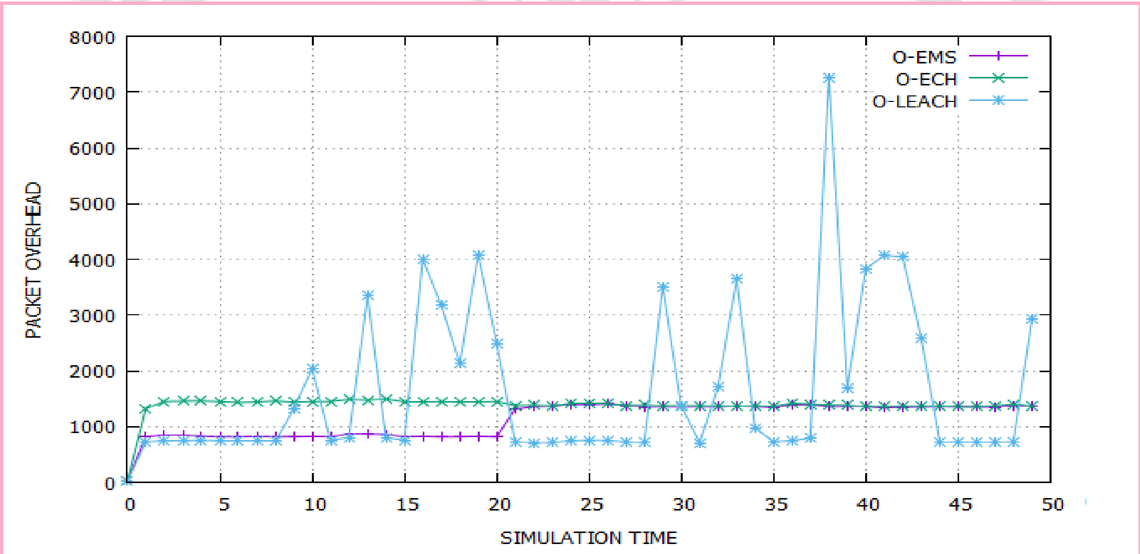

Figure 6: Comparing the overhead of the suggested and current methods for a range of nodes

The control packet overhead of existing and proposed routing protocols with respect to node count is compared in Figure 6. The image makes it evident that there are a lot of LEACH control packets because each data packet includes an acknowledgment. Because the acknowledgment packets are sent after a predetermined amount of time, the control packet overhead of the proposed routing protocol is significantly reduced. Because the ECH protocol did not include acknowledgment packets, its control packet overhead was lower than that of LEACH and EMS.

5. Conclusion:

Exciting changes will occur in the physical, digital, and biological worlds over the next ten years. Although the needs and use cases for Beyond 5G (B5G) are not yet fully understood, an effort has been made to stratify 5G progression and B5G. In order to completely meet the most stringent 5G standards, such stratification, or deconstruction into candidate technologies, will comprise technology scenarios of 5G evolutions. Indeed, the next decade promises to bring about exciting changes in the physical, digital, and biological realms, particularly in the field of telecommunications and wireless technology. Let's delve into the concepts you mentioned regarding the evolution of 5G and the emergence of Beyond 5G (B5G) technologies.
In order to assess packet drops caused by buffer overflow from an intermediate node under various traffic scenarios, this paper creates a probabilistic model. Routing protocols can utilize this model to determine whether or not to send a packet through a specific intermediary node in order to reach its destination. Metrics like packet loss estimation, standard waiting time, and typical queue length in the buffer are adopted for regulating traffic toward the input buffer and identifying whether the node is part of the route or not.

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