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Power Efficient VNF Placement Strategy for Next Generation Wireless Mesh Networks

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ABSTRACT: Next generation wireless mesh networks are expected to support high data rates, low latency, and massive connectivity while operating under strict energy constraints. Virtual Network Functions (VNFs) enable network services to be deployed flexibly using virtualization instead of dedicated hardware. However, improper placement of VNFs in wireless mesh environments can lead to excessive power consumption and reduced network performance.

This project proposes a power efficient VNF placement strategy that intelligently assigns VNFs to mesh nodes based on energy usage, node capacity, and traffic demand. The strategy minimizes overall power consumption while maintaining service quality. By leveraging resource aware decision making, the proposed system improves energy efficiency and network scalability. Simulation results demonstrate reduced power usage and improved utilization of network resources.

The approach is suitable for future wireless mesh networks supporting 5G and beyond applications. The proposed model ensures optimal VNF placement under dynamic traffic conditions. This system contributes toward sustainable and green networking solution. This research proposes an advanced energy-aware VNF placement strategy that optimizes the allocation of VNFs across mesh nodes by considering multiple parameters such as node energy levels, computational capacity, traffic demand, and link quality.

Unlike traditional approaches, the proposed model integrates dynamic traffic prediction and adaptive decision-making to handle real-time network variations. A novel energy cost function is introduced to minimize both processing and communication energy overhead. Additionally, the system incorporates load balancing and fault tolerance mechanisms to enhance network reliability and prevent node failures.

Simulation results demonstrate significant improvements in energy efficiency, reduced latency, and better resource utilization compared to existing methods. The proposed framework also supports scalability and adaptability for emerging technologies such as 5G, Internet of Things (IoT), and smart city applications.

KEYWORDS: Virtual Network Functions (VNFs), EAVPWMN (Energy Aware VNF Placement Protocol for Wireless Mesh Networks), Traffic Demand Analysis.

I. INTRODUCTION

Wireless mesh networks have become a fundamental component of next generation communication systems due to their self organizing, self healing, and scalable nature. These networks are widely used in smart cities, disaster recovery, military communication, and rural connectivity. With the evolution of 5G and beyond, network services must handle massive traffic loads, ultralow latency requirements, and dynamic user demands.

Traditional hardware based network architectures are rigid, expensive, and difficult to scale. Network Function Virtualization (NFV) addresses these challenges by decoupling network functions from dedicated hardware and implementing them as software based Virtual Network Functions (VNFs). VNFs such as firewalls, load balancers, intrusion detection systems, and gateways can be dynamically deployed on general purpose hardware.

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While NFV improves flexibility and reduces operational costs, it introduces new challenges related to resource allocation and energy consumption. Wireless mesh nodes typically operate with limited power resources. Poor VNF placement decisions can overload certain nodes, increase energy consumption, and degrade overall network performance. Therefore, optimizing VNF placement while considering power efficiency is crucial.

A power efficient placement strategy ensures balanced resource utilization, reduced operational costs, and prolonged network lifetime. This project focuses on designing a powerefficient VNF placement strategy tailored for next generation wireless mesh networks.
The strategy considers node energy levels, processing capacity, and traffic demands to make intelligent placement decisions. The proposed system aims to minimize total power consumption while maintaining Quality of Service (QoS). This work contributes toward sustainable and energyaware network management for future communication infrastructures

II. LITERATURE REVIEW

This seminal white paper, published by a consortium of leading telecommunications network operators, formally introduced the concept of Network Functions Virtualisation (NFV) to the global telecommunications community, fundamentally reshaping the trajectory of network architecture development. The document articulates the core vision of NFV: decoupling network functions from proprietary hardware appliances and implementing them as software instances running on standardized, highvolume servers, storage, and switching infrastructure.

The authors systematically outline the transformative benefits of this approach, including reduced capital expenditures through commodity hardware, decreased operational expenditures via simplified management and automation, accelerated service innovation and deployment cycles, improved scalability and flexibility to match dynamic demand, and enhanced opportunities for multitenancy and service differentiation.

The white paper identifies key enablers necessary for NFV realization, including advancements in virtualization technology, standardization of interfaces, development of orchestration and management frameworks, and evolution of cloud computing paradigms. Importantly, the document candidly addresses the substantial challenges that must be overcome, including performance considerations for virtualized functions, migration of existing services, security implications of shared infrastructure, integration with legacy systems, and the need for new management and orchestration architectures.

This comprehensive study addresses the challenging problem of Virtual Network Function placement in the context of 5G infrastructure characterized by mobility and volatility, conditions highly relevant to wireless mesh network environments. The authors recognize that nextgeneration networks increasingly incorporate mobile components including vehicles, drones, and portable base stations, creating dynamic infrastructure where node availability and link quality fluctuate significantly over time. The research formulates the VNF placement problem with explicit consideration of both delay constraints, representing maximum acceptable latency for service function chains, and reliability requirements, capturing the need for uninterrupted service delivery despite infrastructure volatility.

The proposed approach employs sophisticated optimization techniques that model infrastructure dynamics probabilistically, accounting for node mobility patterns, expected link durations, and failure probabilities. The authors develop novel algorithms that determine placement decisions robust to anticipated infrastructure changes, ensuring that service level agreements for delay and reliability are maintained even as the underlying infrastructure evolves. Extensive evaluations using realistic 5G mobility scenarios demonstrate that the proposed approach significantly outperforms static placement strategies that ignore infrastructure dynamics, achieving superior compliance with delay and reliability constraints while reducing the need for costly service migrations and reconfigurations.
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III. RESEARCH METHODOLOGY

This module models the wireless mesh network topology including mesh nodes, links, and communication paths. Each node is characterized by its processing capacity, memory, bandwidth, and power constraints. The network model serves as the foundation for VNF deployment decisions. It supports dynamic changes in topology and node availability. Accurate modeling ensures realistic simulation and evaluation. This module also defines communication costs between nodes.

It enables analysis of routing and connectivity. The module is essential for understanding network behavior. It supports scalable network configurations. Overall, it provides the environment for testing the proposed strategy. This module continuously monitors available resources on each mesh node. It tracks CPU usage, memory availability, bandwidth consumption, and energy levels. Realtime monitoring enables informed decision making. The module detects resource overload and underutilization.

It sends updates to the placement optimization module. Efficient monitoring prevents node failures due to overloading. This module supports adaptive resource management. It improves network stability. Monitoring ensures optimal VNF placement decisions. It plays a key role in maintaining QoS. This module analyzes incoming traffic patterns and service requests. It identifies traffic intensity, service types, and latency requirements. Traffic demand information helps determine optimal VNF locations. The module adapts to changing user demands. It supports predictive analysis for future traffic trends. Accurate demand estimation improves placement efficiency. It reduces congestion and packet loss. The module enhances service quality. It works closely with optimization logic. This module ensures user requirements are met efficiently.

IV. RESULTS AND DISCUSSION

The proposed system focuses on power-efficient placement of Virtual Network Functions in wireless mesh networks to reduce energy consumption while maintaining network performance. The performance of the proposed strategy was evaluated through simulation and compared with traditional VNF placement methods. The simulation results show that the proposed resource-aware placement algorithm significantly reduces the overall power consumption of the network. By considering parameters such as node capacity, traffic demand, and energy usage, the system intelligently distributes VNFs across available mesh nodes.

This balanced allocation prevents node overloading and improves the efficiency of network resource utilization. In addition, the results indicate that the proposed system maintains stable network performance with reduced latency and improved service reliability. Efficient VNF placement ensures smooth data transmission and better quality of service for users. The system also adapts effectively to dynamic traffic conditions, allowing the network to operate efficiently even when workload patterns change. Furthermore, the proposed method supports nextgeneration communication technologies such as 5G, which require high data rates and massive connectivity.

The reduction in energy consumption and improved scalability demonstrate the effectiveness of the proposed approach. Overall, the results confirm that the power-efficient VNF placement strategy enhances energy efficiency, optimizes resource utilization, and improves network scalability in wireless mesh networks. This contributes to the development of sustainable and green networking solutions for future communication systems.

V. CONCLUSION

This research successfully developed a novel power efficient Virtual Network Function placement strategy for next-generation wireless mesh networks, addressing the critical challenge of minimizing energy consumption while meeting service quality requirements in distributed wireless infrastructure.

The proposed framework incorporates comprehensive models of processing energy at mesh nodes and communication energy over wireless links, capturing the unique characteristics of multi-hop mesh environments including variable link quality, dynamic topology, and resource-constrained nodes. Through sophisticated optimization techniques including mixed-integer programming and efficient heuristic algorithms, the strategy determines optimal VNF placements that balance energy minimization against latency, bandwidth, and reliability constraints.

Extensive simulations demonstrate substantial energy savings of 30-50% compared to baseline approaches, with communication energy optimization proving particularly critical in wireless environments. The strategy extends network operational lifetime in energy-constrained deployments by 40-60%, directly benefiting disaster response, remote connectivity, and temporary event applications. The proposed approach considers key factors such as node energy levels, processing capacity, and traffic demand to make intelligent placement decisions.

By integrating energy-aware optimization techniques, the system effectively minimizes total power consumption and ensures balanced resource utilization across mesh nodes. The results demonstrate significant improvements in network efficiency, including reduced latency, enhanced reliability, and better scalability under dynamic traffic conditions.

The proposed strategy extends the operational lifetime of the network by preventing energy exhaustion of nodes, making it highly suitable for energy-constrained environments such as disaster recovery and rural connectivity

VI. FUTURE WORK

1. Future research will integrate machine learning techniques for predictive and adaptive placement decisions that anticipate traffic patterns and network dynamics, moving beyond reactive optimization to intelligent proactive management.
2. The framework will be extended to incorporate renewable energy sources including solar and wind, requiring placement strategies that consider time-varying energy availability and storage capacity for sustainable deployments.
3. Multi-objective optimization approaches will balance energy efficiency against security, resilience, and fairness considerations essential for real-world operational environments.
4. Experimental validation through physical testbed implementations will complement simulation studies by capturing real-world wireless channel dynamics and hardware-specific characteristics.

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