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Evaluation of Power Consumption Technique of IEEE 802.16e Mobile WiMAX with TCP Variants

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Abstract

In IEEE 802.16e mobile WiMAX networks, power consumption methods are controlled by the mobile station (MS) using sleep-mode operation. The paper likely proposes power consumption methods that integrate TCP (Transmission Control Protocol) variants to increase energy efficiency in IEEE 802.16e mobile WiMAX networks. The article likely suggests a power-saving method for IEEE 802.16e mobile WiMAX networks, focusing on the MAC (Medium Access Control) layer and proposing the use of shorter transmission distances to reduce power usage. The article likely includes analyses and simulations to gauge the effectiveness of the proposed power-saving method for IEEE 802.16e mobile WiMAX networks.

Keywords- IEEE 802.16e, Energy consumption, TCP Reno, TCP New Reno, TCP Vegas, TCP Sack1, TCP Fack, Power consumption, transmitted power.

1 INTRODUCTION

IEEE 802.16, commonly known as WiMAX (Worldwide Interoperability for Microwave Access), is indeed a potential standard for next-generation broadband wireless access networks[6]. WiMAX's focus on high-speed multimedia services, last-mile connectivity, and standards development for both fixed and mobile broadband access positions it as a versatile and robust solution for next-generation wireless networks. The IEEE 802.16e mobile standard, authorized in December 2005, supports data rates of up to 15 Mb/s in a 5 MHz channel bandwidth. This high-speed data transmission capability enables mobile stations to deliver broadband connectivity to users while still implementing power-saving features to conserve electricity and prolong battery life. IEEE 802.16e mobile WiMAX networks play a vital role in revolutionizing broadband access in metropolitan areas, offering high-speed multimedia services, cost-effective deployment, and expanded connectivity options for urban and rural communities alike[11]. Correct, the IEEE 802.16 standard defines both the Physical (PHY) Layer and the Medium Access Control (MAC) Layer for WiMAX networks.

To create an effective system for power conservation in wireless systems and networks, a combination of hardware and software-based approaches can be employed. This may include optimizing transmission parameters, implementing sleep-mode operation, dynamically adjusting power levels based on network conditions, and leveraging advanced power management algorithms at both the device and network levels. Furthermore, ongoing research and development efforts are essential for identifying and implementing innovative power-saving technologies, ensuring that wireless systems and networks continue to evolve towards greater energy efficiency, sustainability, and resilience. Indeed, in the IEEE 802.16e MAC protocol, sleep-mode operation is specified to effectively manage limited power resources in mobile subscriber stations (MSSs). The research described in [3] contributes to the understanding of energy consumption in IEEE 802.16e networks by proposing an analytical model that specifically focuses on downlink traffic. This model enables researchers and network designers to analyze, optimize, and improve the energy efficiency of IEEE 802.16e networks, ultimately leading to more sustainable and resilient wireless communication systems.

The structured approach of the article facilitates a systematic exploration of power usage in TCP variants and energy consumption in wireless networks, providing valuable insights for researchers, practitioners, and stakeholders in the field of wireless communication.

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2 MOTIVATION

It's not surprising that numerous academics have recently examined TCP performance in terms of power consumption within the context of mobile WiMAX's IEEE 802.16e standard [16][12][14]. Certainly, TCP's performance can be significantly impacted by various factors unique to specific network environments, leading to challenges in terms of both performance and power consumption. Here's why TCP's performance in such contexts has been the focus of numerous research initiatives [4]. By conducting simulations using a large number of nodes and considering the interactions between TCP versions and ad hoc routing protocols, the article provides valuable insights into the performance and energy efficiency of communication networks in dynamic environments.

3 BACKGROUND

As our study relates to the main TCP variants and ad hoc routing algorithms these are described briefly in the following sub-sections:

3.1 TCP Reno

TCP Reno's combination of Fast Retransmit, Fast Recovery, Slow Start, and Congestion Avoidance mechanisms allows it to efficiently adapt to network conditions, recover from packet loss, and maintain optimal performance in dynamic and congested environments[13].

3.2 TCP New Reno

TCP New Reno combines the benefits of fast recovery from packet loss using the fast retransmit mechanism with the stable and equitable congestion control provided by slow start and congestion avoidance. This makes it a robust and widely used TCP variant for reliable data transmission over the Internet [15].

3.3 TCP Vegas

TCP Vegas offers a proactive approach to congestion control by leveraging RTT measurements to detect and respond to congestion before it leads to packet loss. This adaptive behavior helps improve network performance and efficiency, particularly in scenarios with high latency or varying network conditions [9].

3.4 TCP Sack1

Exactly! The Selective Acknowledgment (SACK) option in TCP allows the receiver to inform the sender about specific packets that have been received, even if they're not sequential. By indicating which packets have been successfully received, SACK helps the sender to identify which packets might have been lost and need retransmission. This selective approach avoids the need to retransmit the entire data window, making TCP more efficient in handling packet loss and accelerating the recovery process [7].

3.5 TCP Fack

It sounds like you're describing TCP FACK (Forward Acknowledgment), which indeed builds upon TCP Reno with SACK (Selective Acknowledgment). TCP FACK utilizes the information provided by SACK to improve the estimation of the amount of data currently in transit, which is crucial for effective congestion control.

3.6 DSDV

Yes, you've accurately described the Destination-Sequenced Distance-Vector Routing (DSDV) algorithm, which was indeed developed by C. Perkins and P. Bhagwat in 1994 for ad hoc mobile networks. DSDV is a table-driven routing method that builds upon the principles of the Bellman-Ford algorithm [8]. One of the key features of DSDV is its solution to the routing loop problem, which it achieves by assigning sequence numbers to each entry in the routing database. These sequence numbers indicate the freshness of the routing information . Typically, even sequence numbers signify the presence of a link, while odd sequence numbers indicate its absence. By incorporating sequence numbers and updating routing information with complete dumps less frequently and smaller incremental updates more frequently, DSDV aims to efficiently distribute routing information among nodes in ad hoc networks. DSDV was indeed one of the earliest routing algorithms developed for ad hoc networks and served as an important milestone in the field of mobile networking. It functions well for constructing ad hoc networks with few nodes.

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DSDV, despite its significance in the development of routing algorithms for ad hoc mobile networks, lacks a formal specification, which has hindered its adoption in commercial settings. However, its foundational concepts have inspired numerous enhanced versions and adaptations proposed by researchers and developers over the years [2].

4 ENERGY CONSUMPTION

In this scenario, the sender node in an ad hoc network needs to reliably transmit a certain amount of data represented by B bytes. To achieve this, it adopts a sliding window protocol, where it sends out a window of packets and then waits for acknowledgments (ACKs) before shifting the window and sending more packets. The sender's behavior can be visualized over time by plotting its current consumption against time, assuming a constant voltage Figure 1 would likely depict the temporal evolution of the sender's current consumption [1]. Considering both transmission and processing energy is crucial for accurately assessing the energy efficiency of network protocols and devices, especially in battery-powered or energy-constrained environments like ad hoc networks or IoT devices. Distinguishing between actual energy consumption (E) and idealized energy consumption (EI) is a useful approach in understanding the efficiency of a system. The total energy less the energy used during the idle time is referred to as the idealised energy.

$$E = E_{idle}(t_{total} - t_{Tx} - t_{Rx}) + E_{Tx}t_{Tx} + E_{Rx}t_{Rx} \quad \text{Eqn. (1)}$$

where E_{idle} is the idle energy consumed by the sender, $t_{total}$is the total time needed to complete the transmission of B bytes, $t_{Tx}$and $t_{Rx}$are the time spent in transmitting and receiving packets, and E_{Tx} and E_{Rx} are the energy expended at the sender for packet transmission and reception.

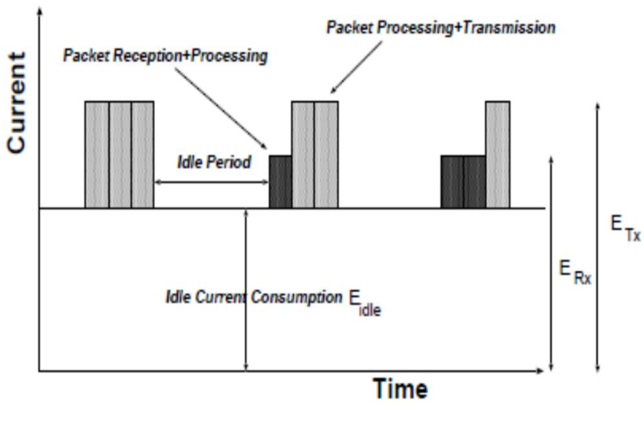

Figure 1: Total energy consumed

In this, we distinguish between actual energy consumption (E) and idealised energy consumption (EI). The term "total energy" alludes to all of the system's energy consumption from the beginning of data transmission to its conclusion. The total energy less the energy used during the idle time is referred to as the idealised energy.

5 SIMULATION METHOLOGY

The architecture have described for simulating the 802.16e system using NS-2 The network topology depicted in Figure 2 includes wired connections between the data server and the BS, with a speed of 5 Mbps and a delay of 2 milliseconds. Additionally, there is a wireless connection between the BS and the MSSs, with a transmission rate of 100 Mbps and a propagation delay of 5 milliseconds This architecture allows for the simulation of communication scenarios in the 802.16e system, including data transmission between the BS and MSSs, resource allocation, scheduling, and mobility management [5]. Using NS-2, simulate various scenarios and evaluate the performance of the 802.16e system under different conditions, such as varying traffic loads, mobility patterns, and network configurations. By analyzing the simulation results, gain insights into the behavior and efficiency of the system and make informed decisions for optimization and improvement.

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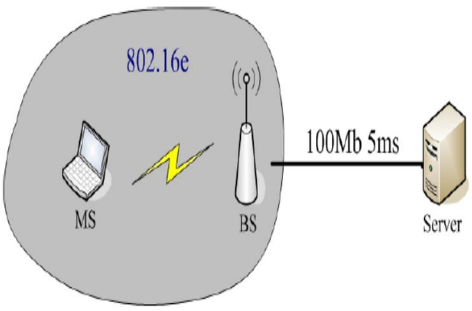

Figure 2: Simulation network topology

The energy consumption parameters used for the simulation of mobile station are summarized in Table 1.

Table 1: The energy consumption parameters

Attributes	Value
Idle power	0.001 Watt
Rx power	0.1 Watt
Tx power	0.2 Watt
Sleep power	0.001 Watt

6 SIMULATION RESULTS

The provided figures illustrate the operational dynamics of the primary TCP variant and modulation techniques in conjunction with power-saving methodologies employed by both base and mobile stations. An additional factor leading to potential disconnection from the counterpart could stem from the loss of the wireless radio signal. In such instances, both sender and receiver nodes endeavor to seek an alternate pathway to conclude the session amid the setback of a link loss occurrence. Across nearly all TCP variants, the sender typically initiates a fresh communication session, reverting to the slow start phase, following the recovery from signal loss. Each instance of wireless connection interruption results in the nodes becoming disconnected. Notably, TCP SACK1 for mobile stations exhibits the most efficient power consumption, albeit with a proportional increase in power usage as speed escalates (see Figure 3). Furthermore, while transmission and reception strength generally increase over time, TCP SACK1 registers the lowest levels (refer to Figures 4, 5, and 6)

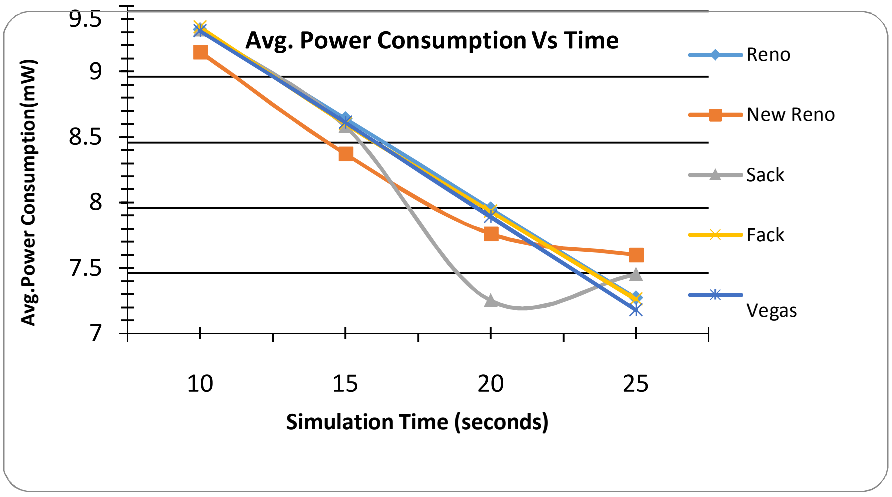

Figure 3: Avg. Power Consumption Vs Time

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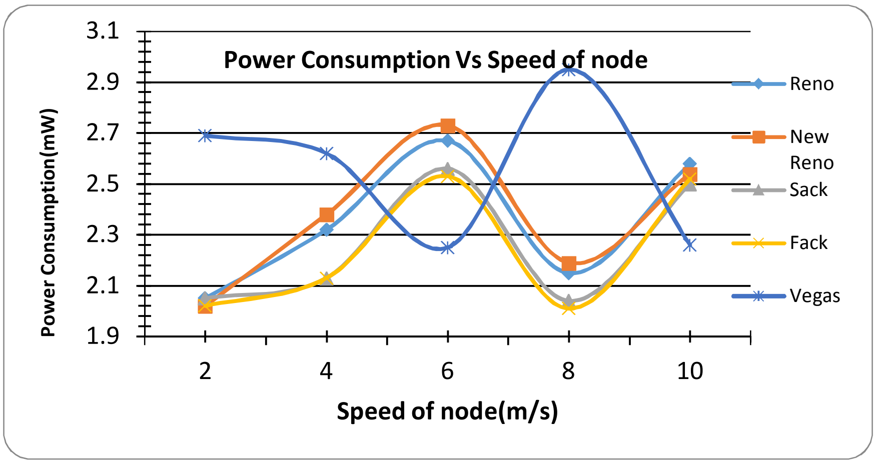

Figure 4: Power Consumption Vs speed of node

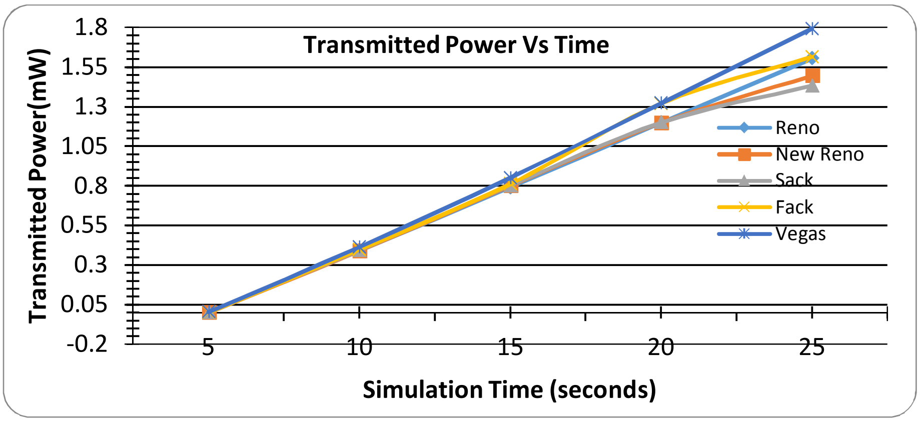

Figure 5: Transmitted Power Vs Time

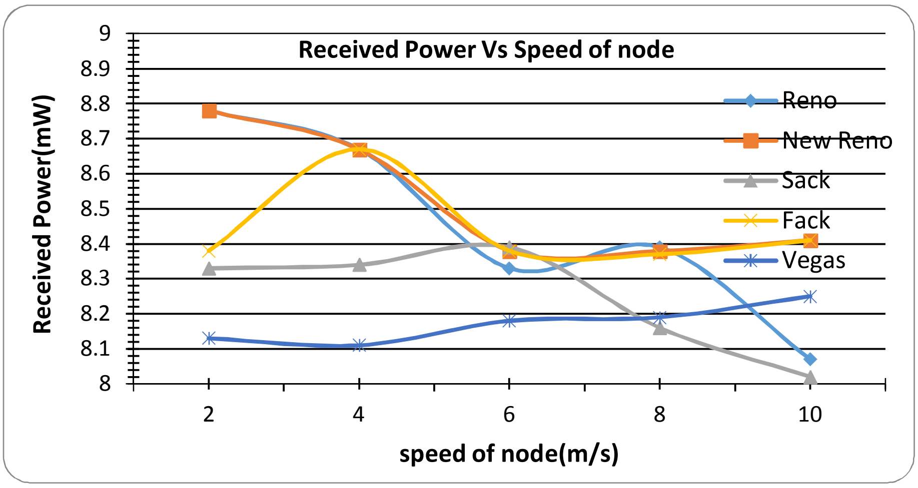

Figure 6: Received Power Vs speed of node

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7 CONCLUSION

The WiMAX energy model-compatible iteration of ns-2.31 was employed to assess the performance of various TCP versions. The simulations encompassed varying simulation durations and node velocities. Notably, in our simulations for mobile stations, TCP Sack1 emerged with the lowest power consumption and minimal transmitted power. To enhance future investigations, alternative simulators such as Qualnet or Opnet could be considered for this task.

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