# Introduction

As the demand for data acquisition and transmission grows with the rapid development of 5G network technologies, Wireless Sensor Network (WSN) has gained attention due to its real-time monitoring capabilities and various applications in the Internet of Things (IoT), including smart factories, environmental monitoring, traffic management, and smart homes. However, WSNs face the challenge of limited battery life, particularly in hard-to-reach locations. To address this issue, many studies have explored trading off energy consumption and efficiency, such as through hybrid energy harvesting models or prioritizing high-energy packets [1]. The redesign of energy-harvesting-based WSNs introducing supplemental energy cells to enhance energy supply is an important step towards addressing these challenges. This redesign can improve the functionality and efficiency of WSN-IoT, thereby providing better performance and security for end users in various fields [2]. In [3], A mathematical model based on Markovian analysis is derived to evaluate the performance of three-machine assembly systems assuming Bernoulli reliability machines, finite buffers, and changeovers. In [4], the authors proposed a system~~s~~ approach for modeling and analyzing batch-discrete manufacturing systems commonly found in various industries. Use a Bernoulli reliability machine model and a virtual buffer concept, with performance evaluation formulae derived. To further conform to the real situation, we propose a redesign of wireless sensor networks based on energy harvesting and regular batteries, and take account of batch inputs.

Over the last few years, various topics concerning WSN have been the subjects of discussion. In [5], a queue with non-preemptive priority is considered in WSN considering multi-event environments containing mobile targets. And in applications where emergency handling is necessary, a superior performance is achieved. In [6][7], both articles propose energy-efficient routing protocols for wireless sensor networks to address the problem of energy depletion, which is critical for the overall lifespan of the network. The proposed solutions aim to minimize energy consumption, increase network lifetime, and improve overall performance. In [8], the authors propose a new cluster protocol enhanced DEEC (Distributed Energy Efficient Cluster) and priority queues to balance energy in WSN networks and prolong network lifetime. In [9], the WSN nodes are modeled as M/M/1/K systems with a finite energy buffer, where each packet requires a unit of energy to start and complete transmission. Additionally, due to impatience, packets in the queue may abandon the system before being serviced by the server [10]. The authors in [11] introduce a new type of networks called a battery-free wireless sensor network (BF-WSN) that harvests energy from the surrounding environment instead of using batteries. Additionally, according to [12], the authors propose a scheme where packets are categorized into high and low priority classes and arrive at the system with varying rates. This classification allows for the high-priority packets to receive preferential treatment in terms of transmission service rates, ensuring the timely and efficient delivery of critical data. Furthermore, according to Shannon's theorem [13], it is possible to enhance the data rate and/or minimize the bit error rate (BER) by boosting the transmission power. The energy problem has always existed in WSN. Hence, it is possible to meet the Quality of Service (QoS) for dependable packet delivery by catering to distinct circumstances and their respective demands [14]. In order to make the system still operate when out of energy, it is mentioned in [15] that by adding a regular battery, the energy in the battery can be used at a certain probability to achieve a balance between energy consumption and system operation. To tackle this challenge, we have taken into account the aforementioned concepts and explored a sensor node that relies on energy harvesting and a conventional battery, with the addition of batch inputs. Afterwards, we integrated the Software Defined Satellite Network (SDSN) architecture proposed in [15] with our sensor nodes to enhance the performance of the WSN.

In this study, we investigate a system where each node has two finite queue storages, with a packet queue, an energy queue, and a regular battery. The packet queue serves as a buffer and sorting space for packets before transmission, while the energy queue is solely used for storing the harvested energy from the environment. We classify arrived packets into two priority classes, high priority (HP) and low priority (LP), with FCFS discipline applied to packets within the same priority class. It is also possible to have two HP packets arrive simultaneously or two LP packets arrive at the same time. HP packets are given non-preemptive priority over LP packets, and packets in the packet queue may be dropped due to impatience. Each packet has the same energy requirement. Furthermore, we consider two scenarios based on the network topology. In the first scenario, we only focus on one node with identical energy consumption for each served packet. In the second scenario, we have a network with three interconnected nodes, each similar to the node in the first scenario. It is important to note that in all scenarios, regular energy may be utilized to improve the system's performance. We derive analytical models and state balance equations for the above scenarios, followed by using an iterative algorithm to obtain steady-state probabilities and performance metrics of interest. We also analyze various parameters to examine their impact on performance and regular battery energy consumption rate. Finally, we write simulation programs in C to verify the accuracy of the analytical results.

This thesis is structured as follows: Chapter 2 outlines the proposed models in depth. Chapter 3 presents the step-by-step derivation of the analytical model. In Chapter 4, simulation models will be developed in C. Chapter 5 will compare analytical and simulation results and offer further explanations. Finally, the last chapter draws several conclusions and proposes directions for future research.