# System model

Our research explores the combination of WSN and IoT applications, which allows sensors to receive energy from both renewable sources and reliable energy sources like regular batteries. We divide packets into four groups based on urgency and number of inputs: one emergent, one non-emergent, two emergent and two non-emergent. Emergent packets contain time-critical information, like alerts for fires, earthquakes, or foreign objects, and must be delivered immediately. In contrast, non-emergent packets contain non-real time information, such as weather forecasts and smart meter data. Each packet is time-sensitive and may be discarded if it fails to meet a certain deadline, indicating that it is no longer useful. There is only one energy source, either harvested from the environment or supplied by the regular battery, can be used to transmit each data packet. Additionally, the energy requirements for each packet vary depending on the level of reliable transmission and QoS required. It's important to note the difference between when multiple packets arrive at once and when they only come one by one.

With the information provided above, we explore two scenarios in our study: (1) only one sensor node is considered and the packets comes one by one with different priority or two with high/low priority, (2) a simplified WSN comprising three interconnected nodes is considered and the way packets come at node 1 is same as scenario 1.

To provide further explanation, we model each node in the WSN as an M/M/1/K system, which includes a finite packet queue, a finite energy queue, and a regular battery. Both packets and energy units arrive randomly in a Poisson process, and the time that each packet can wait in the queue and the time required for its service are defined as exponential distributions. Depending on their application, the arrived packets are roughly classified into two categories: high priority (HP) and low priority (LP). The way that packets come can be divided into four groups: one HP, one LP, two HPs and two LPs. If there is only one seat and here comes two HPs/LPs at once, one of them will be block and the other will enter the packet queue followed the rule below. HP packets have a non-preemptive priority over LP packets, and packets with the same priority follow a first-come, first-served (FCFS) approach. Specifically, when a new HP packet arrives, it is placed in front of any LP packets in the queue, pushing them to the back. However, if an LP packet is already being served, the HP packet at the front of the queue must wait its turn due to the non-preemption policy.

When a node receives a packet, it is either added to the packet queue or rejected and discarded due to queue overflow. If there is enough energy available in the energy queue, the packet at the front of the packet queue will use the corresponding harvested energy to start processing. However, if there is insufficient energy available, a probability value is used to determine if the regular battery can be used as an alternative energy source. If not, the packet will remain in the queue until the next state transition.

In our setup, we have three interconnected nodes. The first node acts as the entry node, the second node acts as the exit node, and the third node acts as the control node. After completing its service at each node, a packet is directed to the next node based on a predetermined routing probability. It's important to note that packets originating from the entry and exit nodes are only allowed to pass through the control node once before being sent back to their respective previous nodes. Additionally, incoming packets are only permitted to enter the system through the entry node and exit after being serviced at the exit node or due to impatience.

## Scenario 1

Within this unit of study, we will focus our attention on a singular sensor node. For the purposes of our investigation, we will assume that each packet - regardless of its priority level - has an energy requirement of one unit. Subsequently, we will analyze the influence of energy usage on the overall performance of the node.

## Scenario 2

Within this unit of study, we examine a network that consists of three interconnected nodes, and this network is an extension of the one considered in Scenario 1. It is assumed that both high priority and low priority packets have an energy requirement of one unit. Subsequently, we investigate how the energy consumption affects not only the overall network but also each individual node within the network.