The three scenarios considered for the energy efficiency assessment are used to conduct benchmarking experiments. The main purpose of the testbed is to show the effectiveness of the proposed approach comparatively and to validate the simulation results presented for the lifetimes of the sensor nodes. The detection accuracy is considered in the section on the evaluation of the proposed deep learning model. The testbed-based evaluation approach employed is similar to the testbed based scenarios (referred to as environment simulation) presented in studies such as References [10, 16, 33, 51]. A small-scale representative is deployed for development and testing purposes. Forest fire warnings are injected to the system by considering forest fire probability similar to the approach used for the simulation to show that with close numbers of forest fire notifications, the simulation and the testbed results confirm each other in terms of energy efficiency. Figure 7 shows the scalar and multimedia sensors used in the testbed implementation. The multimedia sensor with the attached scalar sensor is the sink node as a whole in our setup. The scalar sensor attached is not used for sensing. Instead, it is used as a communication interface to collect incoming packets from the scalar sensors to the sink.

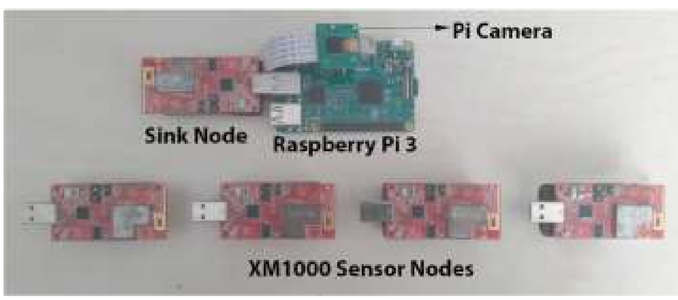

Fig. 7. Experimental setup.

To monitor the voltage levels, a library “battery-sensor” is used in Contiki OS. According to the results of the testbed, when the first scenario is considered (only scalar sensors), the XM1000 sensor nodes discharges two AA batteries in 42.50 days, which is very close to the results of our simulation computed as 43.55 days. The discrepancy is less than 3.5%. For the second scenario, (only multimedia sensors), the lifespan of the multimedia sensors is approximately 11.88 h, which is very close to the simulation results obtained as 11.16 h. The difference between the simulation results and those of the testbed is this time less than 6.1%.

The power sources used for the proposed framework are the same as those of previous experiments for scalar and multimedia sensors. Voltage levels are monitored to specify the lifetime of the nodes. The testbed validates the simulation results for the third scenario as well. While the lifetime of the proposed model is 15.93 h in the simulation, it is 15.66 for the testbed. The difference between the results is less than 1.8%. Results obtained for all three of the scenarios can be summarized as presented in Table 2.

Table 2. Summary of Results

	Scalar	Multimedia	Proposed Framework
Testbed	42.50 days	11.88 h	15.66 h
Simulation	43.55 days	11.16 h	15.93 h
Discrepancy	$\lt \!3.5\%$	$\lt \!6.1\%$	$\lt \!1.8\%$

The evaluation carried out using the testbed assumes that the deployment of the sensors is performed in a way to allow the framework to function as effectively as possible. However, please note that although similar assumptions are used for testbeds in some studies, such as References [10, 16, 33, 51], the correct deployment of the scalar and multimedia sensors is very important for all the frameworks proposed for wildfire detection. The results presented comparatively for the testbed employed, and the simulation shows a good agreement with less than 3.5%, 6.1%, and 1.8% discrepancies for scenarios with scalar sensors only, multimedia sensors only, and the proposed framework, respectively. The results obtained from the testbed implementation also show that systems based on scalar sensors consume less energy than multimedia sensors. However, as stated in many studies dealing with disaster scenarios, we live in a time where multimedia data can be processed autonomously for much greater accuracy, especially when the correct classification is essential. However, since the proposed framework uses the efficiency of scalar sensors together with the accuracy of multimedia sensors, the power consumption of the system is reduced by about 29% when compared to the solutions that are solely based on multimedia sensors.