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Design and Performance Analysis of Automatic Irrigation System using 6LowPAN Networks

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ABSTRACT

WSN (wireless sensor networks) is a widely used IoT (Internet of Things) technology that plays an important role in IoT applications. In agriculture, an optimal irrigation system is needed for high output at the lowest cost and with the least amount of energy. WSN is an important technology for maximising irrigation. The irrigation system based on 6lowpan technology is presented in this research work.The 6LoWPAN network was simulated using Contiki OS and the Cooja simulator. Contiki OS provides the ability to evaluate network output by simulating nodes with Tmote Sky. Smart irrigation systems are used to reduce water and energy consumption while also allowing remote control and monitoring of irrigation systems.Output metrics such as throughput, latency and packet loss were used to evaluate the performance of an irrigation system using 6LoWPAN specifications.

Keywords: Wireless Sensor Networks, 6LowPAN, Contiki OS, Cooja Simulator, irrigation system

1. Introduction

IoT(Internet of Things) allows real objects the power to interact, so it has a wide variety of uses. Home automation, smart cities, wellness control, factory environments, exercise tracking, environmental protection, precision irrigation, waste management, and energy storage are examples of IoT implementations. IoT can be used in smart climate and agriculture applications to raise concern about the atmosphere and agriculture, allowing for more proactive action to achieve the best outcomes [1-3]. A farmer may use an IoT machine in the field to increase production efficiency. IoT uses in agriculture include irrigation systems, greenhouse processing, and pesticide residue detection in crop production. Climate, land, and water are all essential factors in crop production in agriculture. Farmers

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may use sensors in the field to monitor temperature, humidity, and soil moisture levels, which can assist in productive development. Agriculture relies heavily on irrigation [4]. Fresh water is required for crop production in some water-scarce areas. An irrigation scheme that maximises the use of water while consuming a considerable amount of energy necessitates some analysis. In farms, soil sensors are used to quantify moisture and humidity levels, and then water consumption is reduced based on the results.

Automated irrigation is an IoT programme in agriculture that changes irrigation depending on weather conditions. Wireless sensor network technology, which allows small objects with embedded sensors to link to the Internet, can be used for irrigation systems.Wireless IoT connectivity protocols are used to communicate with sensors, actuators, and the base station in a smart irrigation system [5-8]. Low-power Personal Area Network (LPPAN) networking requirements enable low-cost, low-rate, short-range, and low-power consumption communication for battery-powered applications.Low-power IEEE 802.15.4 WPAN is an important IoT technology. The IEEE802.15.4 standard, which was defined in 2000 [9], describes LRWPAN (low rate wireless personal area network). This working group establishes the physical layer and the MAC (medium access control) layer for low-cost, compact wireless network access technologies for laptops, cell phones, and fixed devices.6LowPAN is an LR-WPAN technology based on the IEEE 802.15.4 specification, which was proposed by the IETF community. To have IP network interoperability and consistency with various heterogeneous networks Irrigation scheduling schemes would benefit from the 6LoWPAN norm. IPv6 packets are sent over the IEEE 802.15.4 radio network with the code 6lowpan. In an agricultural area, a range of 6LoWPAN sensor nodes are deployed with a specific configuration.

A set of 6LoWPAN sensor nodes with specific IPv6 addresses are deployed in agricultural fields. Between the PHY/MAC layer and the network layer, the 6LoWPAN communication standard has an adaptation layer that performs header compression of IPv6 packets with sizes ranging from 40 to 211 bytes and connects sensor nodes transparently to the Internet using the TCP/IP protocol. 6LoWPAN technology includes features such as automated network setup via neighbourhood discovery, unicasting, multicasting, and broadcasting, fragmentation support, RPL-IP routing, and mesh topology creation at the link layer (e.g., IEEE 802.15.4). This paper presents a multihop WSN for irrigation smart systems focused on 6lowpan[10] and ContikiRPL [11], as well as a performance analysis of the WSN sensors using metrics such as throughput, packet failure, latency, QoS, and radio duty cycles.The organization of this paper are given as follows: The section 2delves the previous similar works. The system's design of the proposed research work is given in section 3. Performance metrics and discussion of results are explained in section 4. The conclusion and future work are outlined in section 5.

2. Related Work

To manage water in crop fields, an in-field sensor distributed irrigation system has been proposed for variable rate irrigation, which can be controlled and monitored remotely in real time. Wireless networking systems include WSN, Bluetooth, and GSM.The WISC software is used to monitor and evaluate the system's results. Because of Bluetooth technologies, this proposed solution works for a short distance and is not IP-based. In [12] suggested a WSN for precision agriculture that uses a Zigbee network with RFID tags to track agriculture parameters and regulate irrigation and fertigation based on threshold values.In the Zigbee standard, the author creates a tree-based network and suggests a static addressing scheme. The author of this paper avoids using Zigbee and instead creates a network layer based on the IEEE 802.15.4 standard's PHY and MAC layers [13-14].To reduce irrigation system costs in agricultural fields by using Zigbee based on star topology for large-scale remote access the wireless network has been used. The author describes the system's output using a few parameters such as node power consumption, contact range, and system expense.

Just one sensor node is used to test power usage in this article, and there are no actuator nodes. The packet error rate is used to determine the communication spectrum. This paper [15] does not look at the throughput and latency of transmitting data packets.The output valuation of a precision agriculture method based on 6lowpan is discussed in [16]. This paper focuses on the IP network in WSN to overcome the challenges of building global networks for non-IP passed WSN. 6lowpan wireless sensor nodes with temperature and moisture in-built sensors and a gateway-PC with N-anoRouter make up the system architecture.IPv6 client uses a UDP programme to request/receive data from sensor nodes in a 6LoWPAN network, and Wi-Fi access point is used to link IPv6 client and gateway. Experiments based on data transmission reliability time, round trip latency, and packet loss based on payload size [18]. In [19] describe an irrigation scheme that uses fuzzy control and a wireless network to address the problem of crop water waste and soil fertility. This device consists of a wireless sensor network, a monitoring hub, a blurry controller, and the author suggested a solar-module-based lithium-ion battery supply system.In a WSN with Zigbee mesh network topology for connectivity, the system architecture includes sensor nodes, controller nodes, soil moisture sensors, irrigation channel, spray irrigation, and irrigation control valves. The author discusses how to use a fuzzy control algorithm to control irrigation intelligently.

They created a control tool using the interactive programming language LABVIEW to track the status of the WSN and measure wireless transmission using two methods: point-to-point and networking connectivity, which ensures efficient data transmission and device reliability. In terms of data redundancy and the missing packet phenomenon, the experimental results are promising [8]. In [20] it is proposed a methodology for an automated irrigation system that makes efficient use of labour, water, and energy. This paper explores how Zigbee technology was used to solve a power consumption problem. The author introduces the system's architecture in five stages.Three nodes, two sensor nodes, and one receiver node make up the proposed system. Zigbee wirelessly transmits sensed data to a receiver node, and then delivers the data to a microcontroller, which displays the information on the destination node's or PC's LCD. This method works for a specific crop by comparing threshold values and starting automatic irrigation if the running value reaches the threshold value.The author conducted an experimental study of the device, which uses the Zigbee standard to reliably measure soil quality and environmental content while conserving resources. In [12] it is presented a drip irrigation system that saves water resources by combining WSN with soil moisture, soil temperature, and soil pressure sensors. They concentrate on the system's service as difficulties happen, such as pipes bursting or emitters being blocked.They achieve high Quality of Operation by employing a priority-based routing protocol and splitting data sent by the WSN into two distinct traffic levels. They used the NS-2 simulator to simulate the system and obtain results based on priority traffic in delay and packet transmission ratio (PDR) [13].In water-scarce regions, suggested a smart irrigation system to maximise water use. This irrigation system allows for remote control and tracking of agricultural crops, and the

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proposed system is tested using the Contiki Cooja simulator. The proposed framework consists of a Zigbee-based WSN system, as well as other components.6LoWPAN is a smart gateway that connects a Zigbee network to the internet over a mobile network. They use a simulation system to analyse converged and stabilised networks using the RPL protocol, and they implement contikiRPL'sOF0.In [21] introduces an IP-based irrigation method that uses WSN and 6lowpan technologies to improve irrigation scheduling in the crop sector.

3. Proposed Research Work

6lowpan sensor nodes share a shared IPv6 address, which is used as a prefix in the WSN. This WSN links to other IP networks through a firewall, the 6lowpan router. In the LoWPAN network, the edge router performs neighbour exploration, type routes to handle traffic in and out of the network, and header compression for IP packet transmission. To send and receive IPv6 packets, different LR-WPAN nodes are marked by different specific IPv6 addresses. As a transport protocol, these nodes use ICMPv6 traffic such as ping and UDP. A sensor node serves as an edge router in a 6lowpan WSN, while the remaining nodes serve as source nodes, sending temperature, light, and humidity values to the sink node.

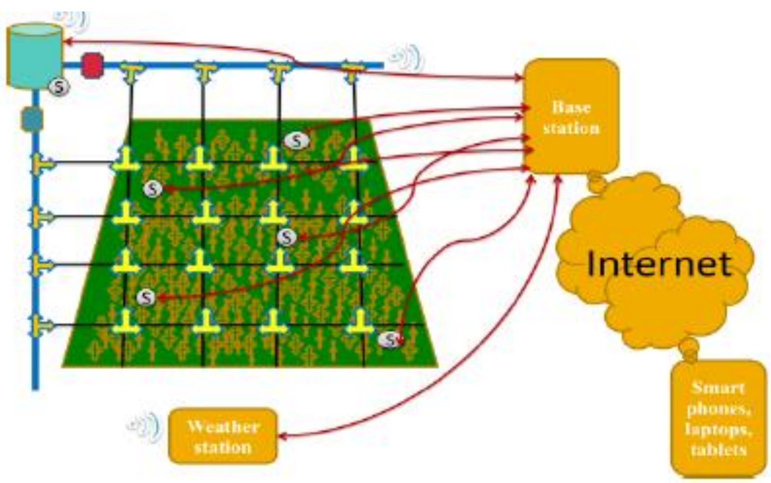

Figure 1: Smart Irrigation System Architecture

Figure 1 is a schematic diagram of Irrigation system and its architecture consists of a base station with a controller to control actuators and a portal server to link to the Internet, as well as various wireless sensors and actuators installed in agricultural fields. PAN with low power and low rate is made up of 6LoWPAN sensor nodes that monitor soil temperature, humidity, and node power consumption.

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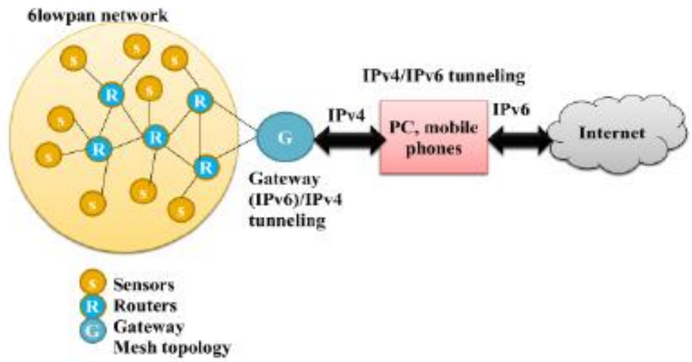

Figure 2: Node link of IPV6 with Internet

This sink node sends data to a server through a gateway that stores and analyses the data. After processing at the server, the server sends an order to the controller at the base station, and the controller controls the actuators as required. To connect to the Internet, a gateway is installed between the sink node and the 6lowpan WSN. The RPL routing protocol defines the LLN routing specifications (low power and lossy networks). The node linkage is shown in Figure 2.RPL routing creates a DAG (Directed acyclic graph) with the sink node as the DAG root, which is the DODAG root of the destination based DAG (DAG). This DODAG optimises using the DODAGID identifier and a help objective feature (OF).

The objective code point indicates parent selection in the graph, hop count, predicted transmission count, capacity, and latency matrices (OF identified by an OCP). By assigning a rank number to each node, the location and distance of each node from the root can be calculated. 6lowpan sensor nodes can send data to any of their one-hop neighbours using wireless mesh networking. Upcoming Data is forwarded to the destination by neighbour, who acts as a router. To connect, nodes take the shortest path with the fewest hops. Nodes benefit from the self-healing aspect of this topology, as well as its scalability.

4. Performance Evaluation

4.1 Experimental Setup

The system simulation scenario depicts a real-world system implementation. Contiki operating system and default network Cooja simulator for wsn are used to simulate irrigation systems. For IP networking, Contiki employs the uIP TCP/IP stack. The Cooja simulator offers a user-friendly and intuitive graphical user interface, as well as simple simulation setup and analysis. Cooja is based on Java and allows developers to create applications in C using the Java native interface.

Tmote Sky used motes built on the MSP430 microcontroller with 10 KB RAM and an IEEE 802.15.4 radio link to simulate them. In the Cooja radio environment, the Unit Disk Graph medium is used to choose a propagation model that shows the transmission and interference range of any mote, which is useful for deciding where motes should be placed in a scenario.

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6 lowpan has underlying SHT11 sensor, an LBR, is used by 10 RPL sender nodes in the network to send temperature and humidity values to sink nodes as tools (LLN Border Router). UDP, SICSLoWPAN IPv6 are among the motes derived from the uIPv6 protocol stack. To link the network and the Internet, the border router employs the built-in network interface TUNSLIP utility (a serial-based interface known as SLIP).

For collecting data from motes, Cooja provides the Collect View tool. It can be used to monitor the time it takes to form the first sender-receiver pair in the network, the time it takes to connect all nodes to the network tree (fully convergence), the time it takes to stabilise the entire network after convergence, and the time it takes for each node's ETX (estimated transmission count).

4.2 Experimental Results

(i). Throughput

The rate of successfully delivered data to destination nodes deployed in a network divided by the convergence field, which is measured in bits per second, is the throughput metric. For the various motes at hops 2 to 11, the impact of received packets over time and received packet per node on 6LoWPAN throughput is shown below for hops 2 to 11.

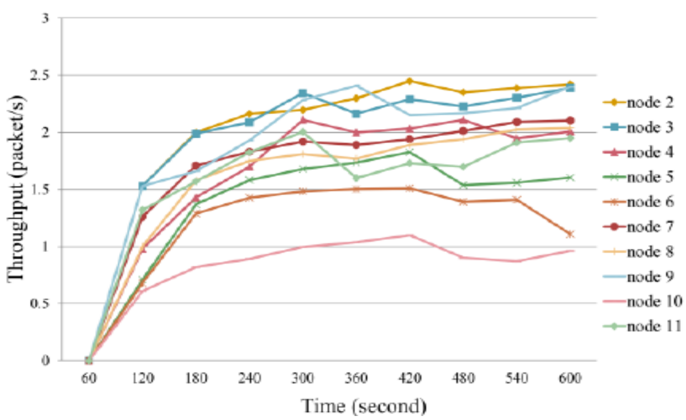

Figure 3. Average Throughput

In simulation time, throughput shown in Figure 3, increases rapidly as the number of received packets increases. In the absence of duplicate packets, the received packet rate was varied from 1 to 100 packets per second. The temperature and humidity sensor's HTTP server was used to send get requests. (Total simulation time*(length of request+ length of answer in bits))/number of active http request/response pairs.

(ii). Latency

The average time it takes to travel from source to destination is known as the average end-to-end delay. The term "latency" refers to the time it takes for data to be processed is shown in Figure 4. The end-to-end delay on this 6lowpan network is lower. The explanation for this is that sender nodes look

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for a non-congested DODAG root (parent) to send packets to first. The number of 2*max latency and transmission delay is the end-to-end delay. It's estimated based on the round-trip time.

Latency is negligible when all nodes are in transmission range with the sink node, but when nodes are not in transmission range, the average delay per packet changes with each instance of time. The ICMP ping echo packet's round trip time is used to determine latency and is based on the MAC protocol and when the next channel sample occurs before the MAC can detect the ping packets.

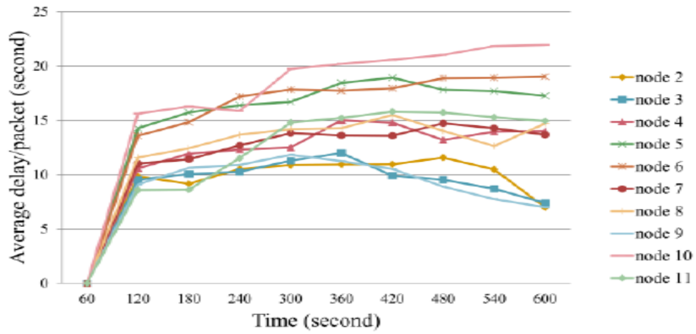

Figure 4. Latency

(iii). Packet Loss

The HTTP client submitted a GET request in the simulation case, and if the requests were not acknowledged, packet loss occurred. As buffer overload occurs in the presence of ambient noise and wireless channel loss, the total number of missed packets per second increases. Changing the Tx/Rx ratio and the location of nodes in the network in Cooja will simulate packet loss. Packet loss does not occur when the Tx/Rx ratio is 100 percent. Packet loss occurs as the distance between the sink and source nodes grows, especially between the 10th and 6th nodes is shown in Figure 5.

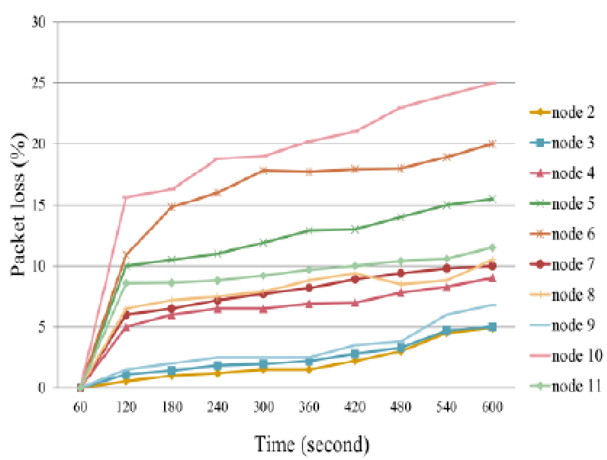

Figure 5. Packet Loss

5. Conclusion

A 6lowpan based irrigation system was proposed in this paper. In the agricultural sector, a smart irrigation scheduling system provides water and power optimization as well as increased efficiency. The 6lowpan network improves LWPAN and gateway interoperability. Irrigation in crop fields using this technology would be beneficial in terms of low cost and high precision.We used the Cooja simulator to test the efficiency of the 6lowpan network. The aim of this paper is to look at how IP-based LR-WPAN performs in terms of QoS parameters. QoS matrices such as throughput, packet loss and latency are used to assess the overall QoS of the 6lowpan network for irrigation.

According to simulation performance, a large number of packets are received with a high throughput and average latency. As the number of intermediate nodes grows, so does power consumption and packet loss. When the radio service cycle is reduced, the beacon interval time for that node is reduced as well, indicating less power usage and a longer battery life.This study will be expanded in the future to include a real-time scenario in the area. For network simulation, various networking technologies such as Zigbee, some WLAN and WWAN such as Wi-Fi and Lora, Sigfox, and others will be used. Different simulators can be used to test QoS parameters.

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